HAY RIVER BASIN OVERVIEW

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Egon Borke

Prepared jointly by:

Environmental Planning & Assessment
Division
Department of Renewable Resources
Government of the Northwest Territories

and

Inland Waters Directorate
Department of the Environment
Government of Canada

PREFACE

Sound planning is essential to the wise development of any resource and adequate understanding is absolutely necessary if subsequent plans are to be meaningful. So it is with the water resources of northern Canada, a fundamental element in that region's economic development. The nature of the resource dictates that river basins constitute the basic planning unit for which information must be assembled.

The Mackenzie River Basin Committee's multi-year study, concluded in 1981, made nine recommendations, first of which was:

> "It is recommended that the jurisdictions at an early date conclude an agreement through which trans-boundary water management issues such as minimum flows, flow regulation, and water quality can be addressed at jurisdictional boundary crossing points in the Mackenzie River Basin, and which establishes a permanent board to implement the provisions of the agreement."

The concept of assembling information for river basin planning units was thus directed to transboundary water. Because of the obvious interest of the Government of the Northwest Territories as a potential provincial negotiator and Environment Canada's involvement, deriving from the Canada Water Act, a joint study founded on a Letter of Understanding dated July, 1983 was undertaken (Appendix A). Study results are presented in subsequent sections for the first of the following eight river basins which straddle the border between the Northwest Territories and neighbouring jurisdictions within the confines of the greater Mackenzie River Basin:

1. Hay River
2. Peel River
3. Big Fish River
4. Buffalo River
5. Little Buffalo River
6. Talston River
7. Slave River
8. Liard River

HAY RIVER BASIN OVERVIEW

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EXECUTIVE SUMMARY

HAY RIVER BASIN OVERVIEW

The format of the Hay River Basin overview will serve as a prototype for the overviews of the seven remaining basins with interjurisdictional concerns in the larger Mackenzie River system. Most of the Hay River Basin lies within British Columbia and Alberta; only the lower portion is located within the Northwest Territories (NWT). Of the total area of 48 000 km , 6.5 percent is in the NWT, 19.5 percent is in British Columbia, and 74 percent is in Alberta.

The entire basin is located in the northern portion of the Great Central Plain in the sub-region known as the Alberta Plateau. The geology consists mainly of sedimentary bedrock, i.e., shale, sandstone, limestone and dolomite. Soils are derived from native rock, till and from organic deposits. Pockets of permafrost are also found within the basin. The vegetation is typical of the boreal forest except for an extensive grassland and marsh region in the Hay-Zama Lakes area.

Basin climate is classified as boreal, a colder version of continental climate. On average the annual precipitation approximates 405 mm with higher values to the west and lower ones to the east. Precipitation losses to groundwater and evaporation are similar to those further south; less than 20 percent of the total precipitation appears as surface runoff.

Of the eight hydrometric stations within the basin, seven are located in Alberta. Hydrometric records are of variable length, the longest period being for the Hay River station near Hay River, NWT which has continuous records from 1964 to the present. The common period of record for all eight stations extends back to 1975.

Four water quality sampling sites are located within the basin, three on the lower main stem and one on Steen River tributary. These data show that turbidity and color are directly proportional to flow volume and that total dissolved solids and conductivity are inversely related to flow volume. The natural waters are high in calcium and bicarbonate which are important as buffers for acidic precipitation. Although nutrients and some metals are near recommended limits, they are considered to be relatively harmless to the aquatic biota, because they are linked to suspended particles in the water column and are basically unavailable. No historic data for organic chemistry exist, thus constituting a data gap of some concern in view of hydrocarbon production and pipeline transport in the Hay-Zama Lakes region.

The river channel patterns are mature, well-developed systems with some evidence of structural control from bedrock formations in the Chinchaga River sub-basin and morainal control south from Zama Lake. The lowlands surrounding Hay-Zama Lakes behave as temporary, annual storage basins, thereby making the annual hydrograph shape less peaked downstream than it is in major tributaries such as the Chinchaga. No significant lake storage aside from Hay-Zama exists in the basin. The annual variation in streamflow is considerable, in the range of two orders of magnitude, eg. from eight cubic meters per second (m^3/s) to

1080 m^3/s in 1977. Only one flood in 1977 at the lower station near Hay River, NWT was from mid-summer rains; all others were the result of snowmelt in the spring. Statistical flood frequency analysis suggests that a 50 year flood approximates 1250 m^3/s at Hay River, NWT. Similar analysis done for annual periods of low flow of at least seven days duration showed the average low flow at Hay River, NWT to be 1.8 m^3/s.

The present impact of development within the Hay River area is minor. Agricultural activity is limited to market gardens between Enterprise and Hay River, NWT and one small cereal grain farm north of the border. There is potential for agricultural expansion in the NWT and there has been considerable pressure from existing operators to expand their holdings. With an increased emphasis on renewable resource development and the development of an agricultural policy, agricultural development could expand in the NWT.

Forest production within the Hay River Basin is presently occurring along the Chinchaga River in Alberta and in the Cameron Hills area, NWT. Patterson's Sawmill at Hay River produces about 10 000 m^3 of lumber annually.

One transportation corridor, containing the southern highway link to the NWT and Hay River-Pine Point railway, enters the basin near Hutch Lake and parallels the mainstem river from Meander River settlement to the town of Hay River.

Several aspects of hydrocarbon development both from the Hay-Zama oil and gas fields and from the Norman Wells pipeline river crossings are of concern; the two most important are the potential for hydrocarbon pollution of Hay River water and the long-term effects of increased river salinity resulting from salt water injection into contributing aquifers.

II. HAY RIVER BASIN BIOPHYSICAL OVERVIEW

1.0 Introduction

The format of this overview study of the Hay River is designed to serve as a prototype or pattern for subsequent studies. Compared to some of the other interjurisdictional basins identified for overview study, there is a large hydrological data base and there has been some degree of development. Because of this, most of the discussion points in the first overview plans were deemed to be pertinent to the Hay River Basin overview. A final point in its selection as a prototype was its size; sufficiently small to avoid the complexities foreseen for the two much larger basins, the Slave and the Liard, but still displaying a good data base for applicable topics.

The overview is a combination of input from Inland Waters Directorate, Environment Canada and from Environmental Planning and Assessment Division, Department of Renewable Resources of the Government of the Northwest Territories, who prepared the biophysical and resource use portion, respectively.

2.0 Geographic Aspects

2.1 Location

The general location of the Hay River Basin within Canada is shown in Figure 1. From it we can see that the basin crosses two provincial borders so that its area is shared between British Columbia (B.C.), Alberta and the Northwest Territories (NWT). The general trend of the basin is to the northeast, making the NWT the recipients of surface runoff waters from B.C. and Alberta. The headwaters of both the main

stem Hay River and the Chinchaga River, a major tributary, are in B.C. but it is evident from an inspection of Figure 2 that the bulk of the basin lies within Alberta. Reference to National Topographic Series (NTS) maps, NP-11, NP-12, NO-11 and NO-10 at a scale of 1:1 000 000 shows that the basin lies between 57° and 61° North latitude and between 115°30' and 121°30' West longitude.

2.2 Size

As noted in Figure 2, the longitudinal transect of maximum length from the drainage divide in the headwaters of the Chinchaga River to the Hay River estuary at the town of Hay River measures 490 km. Greatest width measured at right angles to the longitudinal transect is 248 km. The average width is much less, however; the arithmetic mean of nine transverse measurements diagrammed in Figure 2 shows it to be 105 km.

Accurately defined drainage areas within the basin are available for sub-areas above hydrometric gauging stations. Total area of the basin is 48 100 km². The breakdown of the total area and hydrometric gauging station discharge sub-areas are shown in Table 1. Figure 3 shows hydrometric gauging locations within the basin. It can be inferred from their location that sufficient data exist to define flow at the Alberta/NWT border with some confidence - not the case for the B.C./ Alberta border.

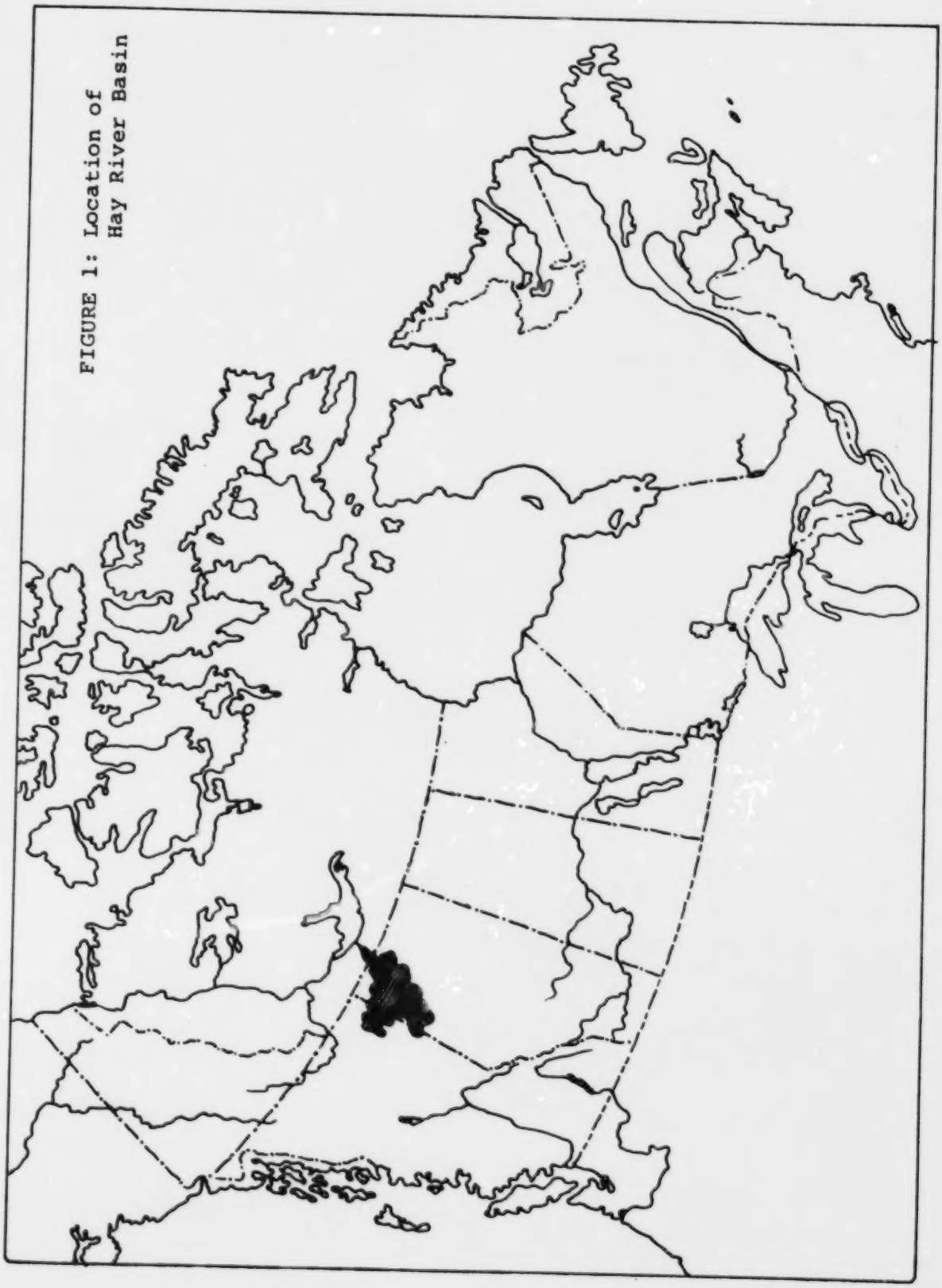


FIGURE 1: Location of Hay River Basin

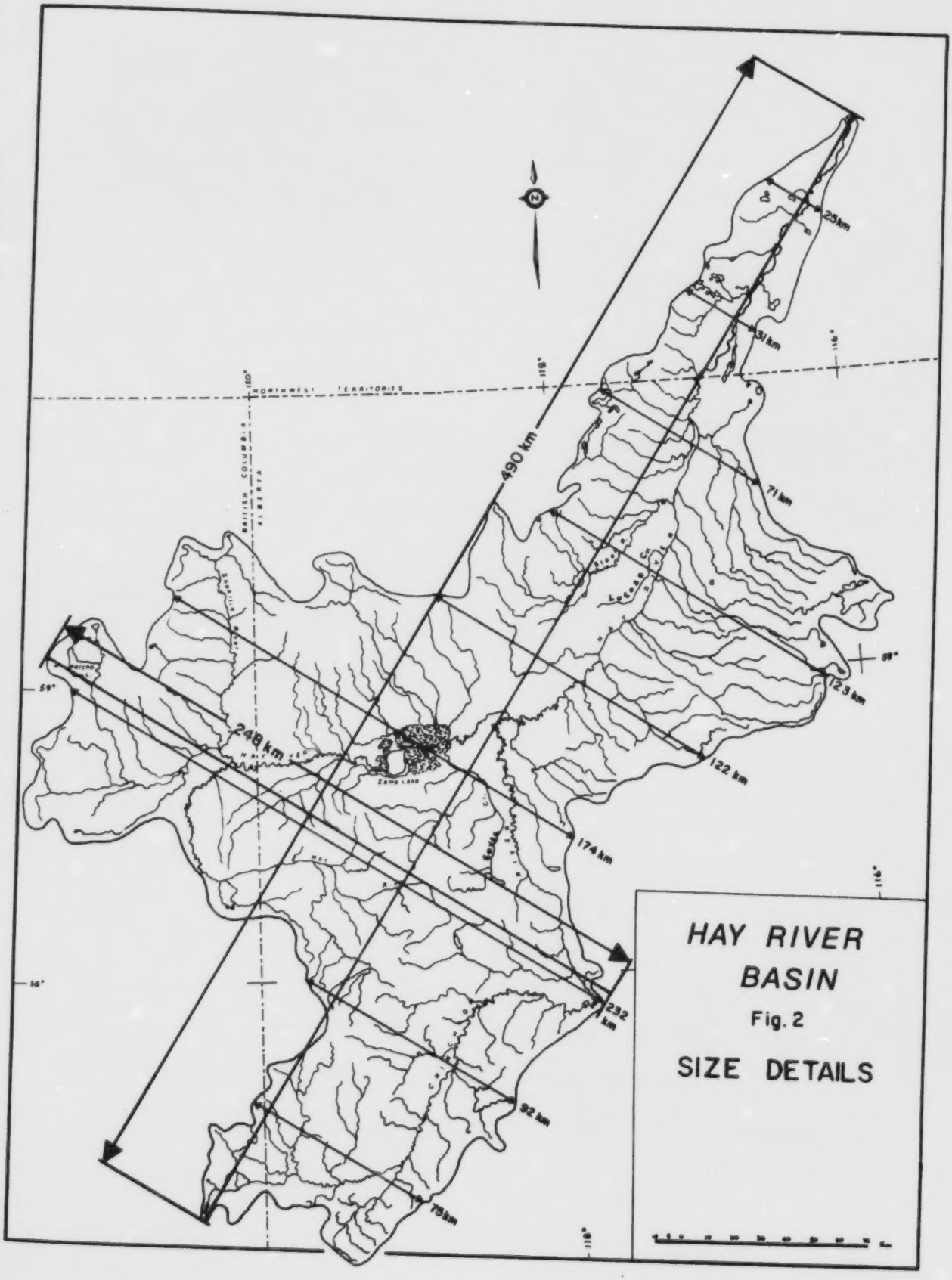

490 km
248 km
25km
31km
71km
123km
122 km
174km
232 km
92 km
75km
NORTHWEST TERRITORIES
ALBERTA
Zama Lake
HAY RIVER
BASIN
Fig. 2
SIZE DETAILS

Table 1: Hay Basin Area Distribution

Part A: Distribution by Boundary

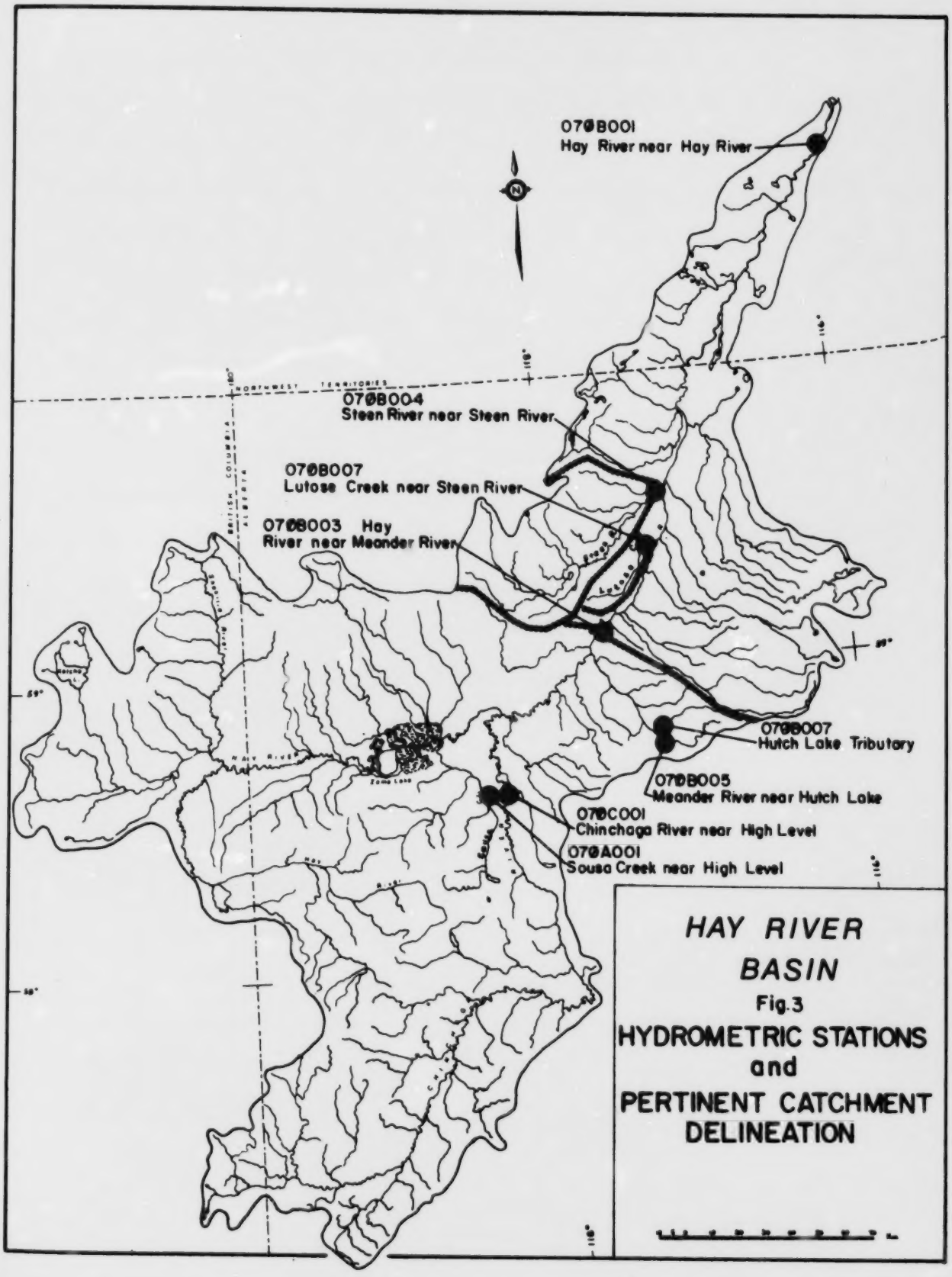
	km	Fraction
Total area	48 000	1.000
NWT Portion	3 100	0.065
B.C. Portion	9 400	0.195
Alberta Portion	35 600	0.740
Non-NWT drainage (B.C. & Alta.)	45 000	0.935

Part B: Hydrometric Station Drainage Areas

Hay River near Hay River - 090B001	47 900	0.996
Hay River near Meander River - 070B003	36 900	0.767
Chinchaga River near High Level - 070G001	10 800	0.224
Steen River near Steen River - 070B004	2 610	0.054
Sousa Creek near High Level - 070A001	818	0.011
Hutch Lake tributary near High Level-070B007	507	0.002
Lutose Creek near Steen River - 070B006	292	0.001

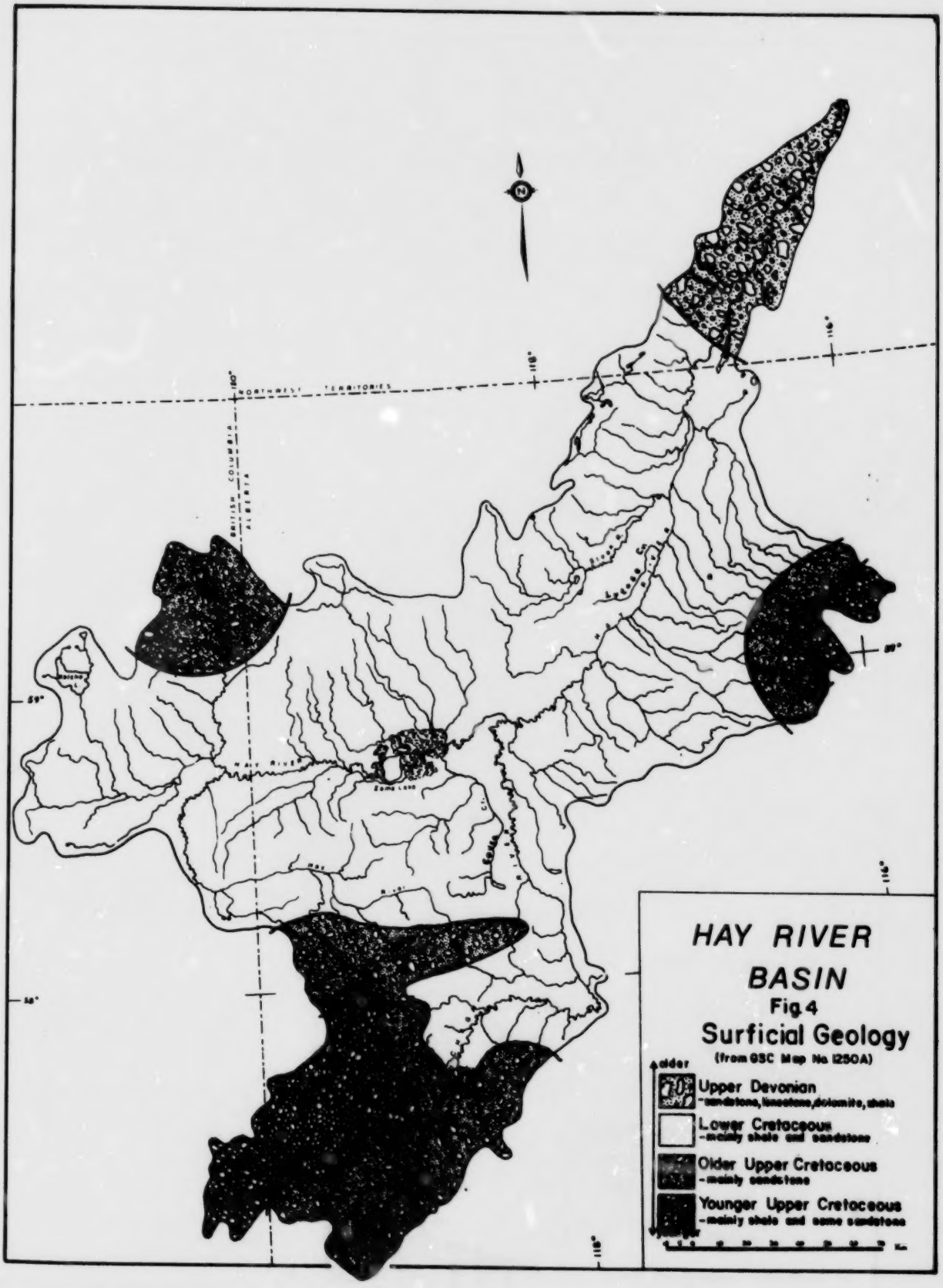
2.3 Geology and Physiography

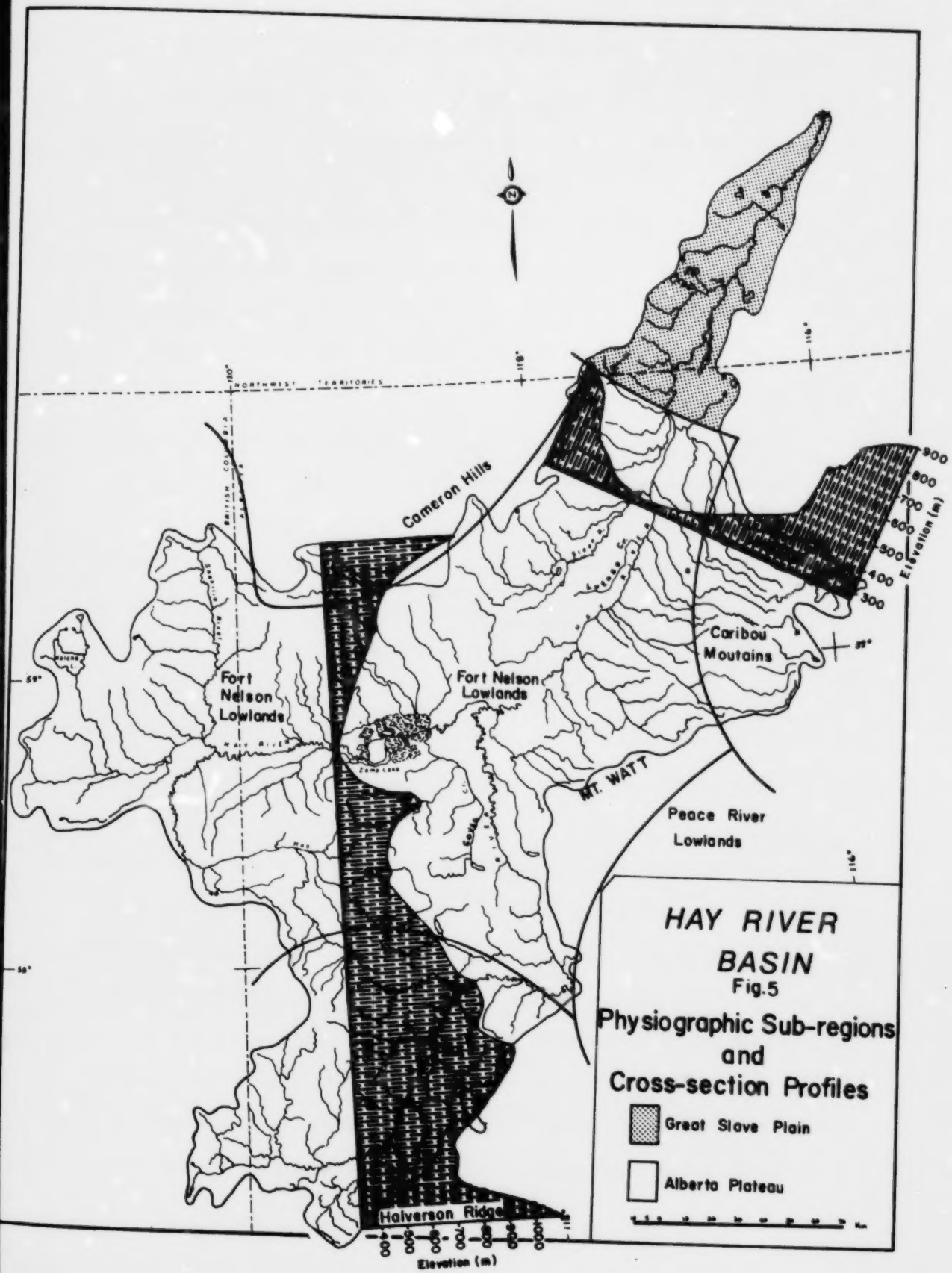
Douglas (1970) indicates that the Hay Basin is located in the western border of the Interior Platform, a region characterized by basement rocks of granitic/gneissic composition which are overlain by varying thicknesses of sedimentary rocks. The sedimentary rocks consist of carbonates, shale and sandstone deriving from the Devonian and Cretaceous periods. In most of the basin the underlying rocks are mantled by glacial till of Quaternary age of variable thickness, in the range of 150-180 m thickness. Although the surface evidence of Quaternary glaciation indicates ice movement from the east and north-east, it is interesting to note that the influence of Cordilleran ice extended to the western borders of the Hay Basin (Prest, 1970). Prest also indicates that the Hay River drainage system remained basically unchanged by Quaternary glaciation and was in fact a mature, dendritic


07ØB001
Hay River near Hay River
07ØB004
Steen River near Steen River
07ØB007
Lutose Creek near Steen River
07ØB003 Hay
River near Meander River
07ØB007
Hutch Lake Tributary
07ØB005
Meander River near Hutch Lake
07ØC001
Chinchaga River near High Level
07ØA001
Sousa Creek near High Level
HAY RIVER
BASIN
Fig.3
HYDROMETRIC STATIONS
and
PERTINENT CATCHMENT
DELINEATION

drainage system in the Tertiary period. In a hydrologic sense, the nature of the underlying rocks and the relatively thick layer of till suggest that infiltration is an important constituent of the hydrologic cycle. The surficial rock exposures within the basin are quite uniform, being mainly Cretaceous shales and sandstones south and west of the Alberta/NWT border and Devonian limestones and dolomites in the lower basin north of 60° latitude as shown in Figure 4. Geologically speaking, therefore, we would expect surface water runoff characteristics at the NWT border to be fairly uniform in a spatial sense.

Physiographically, the Hay River Basin is located in the north-central portion of the Interior Plains region of Canada (GSC Map 1254-A, 1970). Two sub-divisions within the basin correspond quite closely to underlying rock classifications so that the Devonian bedrock area of the basin in the NWT is found in the Great Slave Plain while the remainder of the basin south of 60°N latitude is confined to the Alberta Plateau. A further sub-division, termed the Fort Nelson Lowland, distinguishes the central portion of the Hay River basin from bordering uplands of the Alberta Plateau proper, except for the region southeast of the Lower Chinchaga River where the Fort Nelson Lowlands join the Peace River Lowlands. The sub-divisions of the Interior Plains as they apply to the Hay River Basin are shown in Figure 5 as are current names for the bordering highlands of the Alberta Plateau. Also shown in Figure 5 are two transect profiles, A-A1 and B-B1, to illustrate typical elevational difference.


HAY RIVER
BASIN
Fig. 4
Surficial Geology
(from GSC Map No. 1250A)
older
Upper Devonian
-sandstone, limestone, dolomite, shale
Lower Cretaceous
-mainly shale and sandstone
Older Upper Cretaceous
-mainly sandstone
Younger Upper Cretaceous
-mainly shale and some sandstone
NORTHWEST TERRITORIES
ALBERTA
BRITISH COLUMBIA
HAY RIVER
Zama Lake
Meander R.
Footner L.
Boyer R.
Steen R.
Tathlina L.
Hay R.
Meander R.
Zama Lake
Zama Cr.
Footner L.
Boyer R.
Steen R.
Tathlina L.


Cameron Hills
Fort Nelson Lowlands
Fort Nelson Lowlands
Caribou Moutains
MT. WATT
Peace River Lowlands
Halverson Ridge
Elevation (m)
900
800
700
600
500
400
300
Elevation (m)
HAY RIVER BASIN
Fig.5
Physiographic Sub-regions and Cross-section Profiles
Great Slave Plain
Alberta Plateau

The Hay River Basin lies in the southern portion of the zone of discontinuous permafrost (Brown, 1970). At the town of Hay River permanently frozen ground of ten m thickness has been noted under an active layer two or three m in depth. South from Hay River, permafrost becomes increasingly sporadic and is confined to areas overlain with heavy organic mats. The effects of permafrost on infiltration rates would thus appear to be minimal.

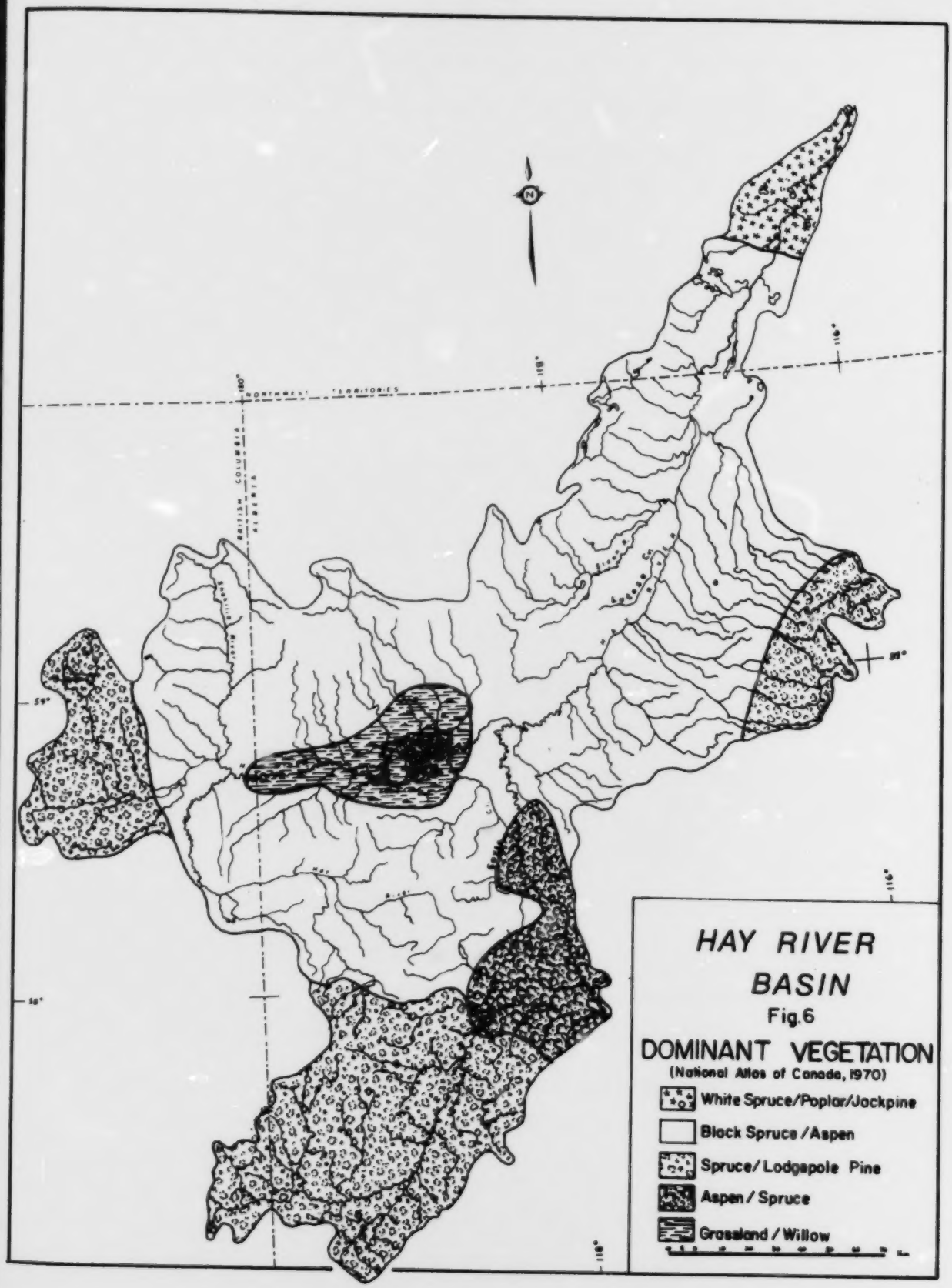
2.4 Soils and Vegetation

The mineral soils within the basin are derived from Laurentide till and the products of local weathering. In the Fort Nelson Lowlands, mineral soil constituents include large complexes of soils of lacustrine or lake origin. Floodplains and low-lying river valleys within the basin contain many reaches of alluvial soils. Because of poor drainage in the lowlands portion of the Hay Basin, the mineral soil associations are dominated by extensive organic soils common to wetlands. Peat soils are especially prevalent in the Hay-Zama Lakes region. Both the native soils and the poor drainage in low-relief terrain have given rise to characteristic marsh and bog vegetation. River channels within the lowland exhibit long reaches of meandering river pattern, an indication of channel maturity in a graded river regime (Strahler, 1971). Fine silt, clay and organic soils in the region around Hay-Zama Lakes dictate the development of narrow, single channel river systems of insufficient capacity to accomodate floods much greater than the mean annual flood. These characteristics serve to maintain the extensive wetlands surrounding Hay-Zama Lakes.

The National Atlas of Canada (1970) locates the Hay Basin within the boreal forest of Canada. There are sub-regions within this general classification, however, with differing dominant species as shown in Figure 6. Black spruce and aspen are the dominant species in the central portions of the basin with the exception of a narrow band of white spruce, poplar and jack pine near the town of Hay River. Chinchaga River headwaters are characterized by different tree species such as lodgepole pine and aspen. An exception to the boreal forest environment is found in the Hay-Zama Lakes wetland region. The largest natural grassland prairie of northern Alberta is found around the lake complex and extends to the north and west of Zama Lake. The prairie is susceptible to flooding in high-water years so that dry land vegetation and marsh grasses are interspersed, dependent on local relief. Willow and aspen bluffs are dotted throughout the prairie (Mackenzie River Basin Report MRBC Supplement 1, 1982). Wetlands are extensive in the Fort Nelson Lowlands; the National Atlas (1970) classification in 10 000 km grid units lists wetland fractions in excess of 30 percent for this area.

2.5 Climate

Trevartha and Horn (1980) place the Hay Basin in a boreal climate classification which "...has many features in common with a temperate continental climate; it differs mainly in that, because of its location farther poleward, it is more severe". The difference is more of degree rather than kind; and boreal climate is characterized by long, severely cold winters, short cool summers and brief falls and springs. MRBC (1982) suggests a 100 day frost-free period. The chief


HAY RIVER
BASIN
Fig.6
DOMINANT VEGETATION
(National Atlas of Canada, 1970)
White Spruce/Poplar/Jackpine
Black Spruce /Aspen
Spruce/ Lodgepole Pine
Aspen / Spruce
Grassland / Willow
N
NORTHWEST TERRITORIES
BRITISH COLUMBIA
ALBERTA

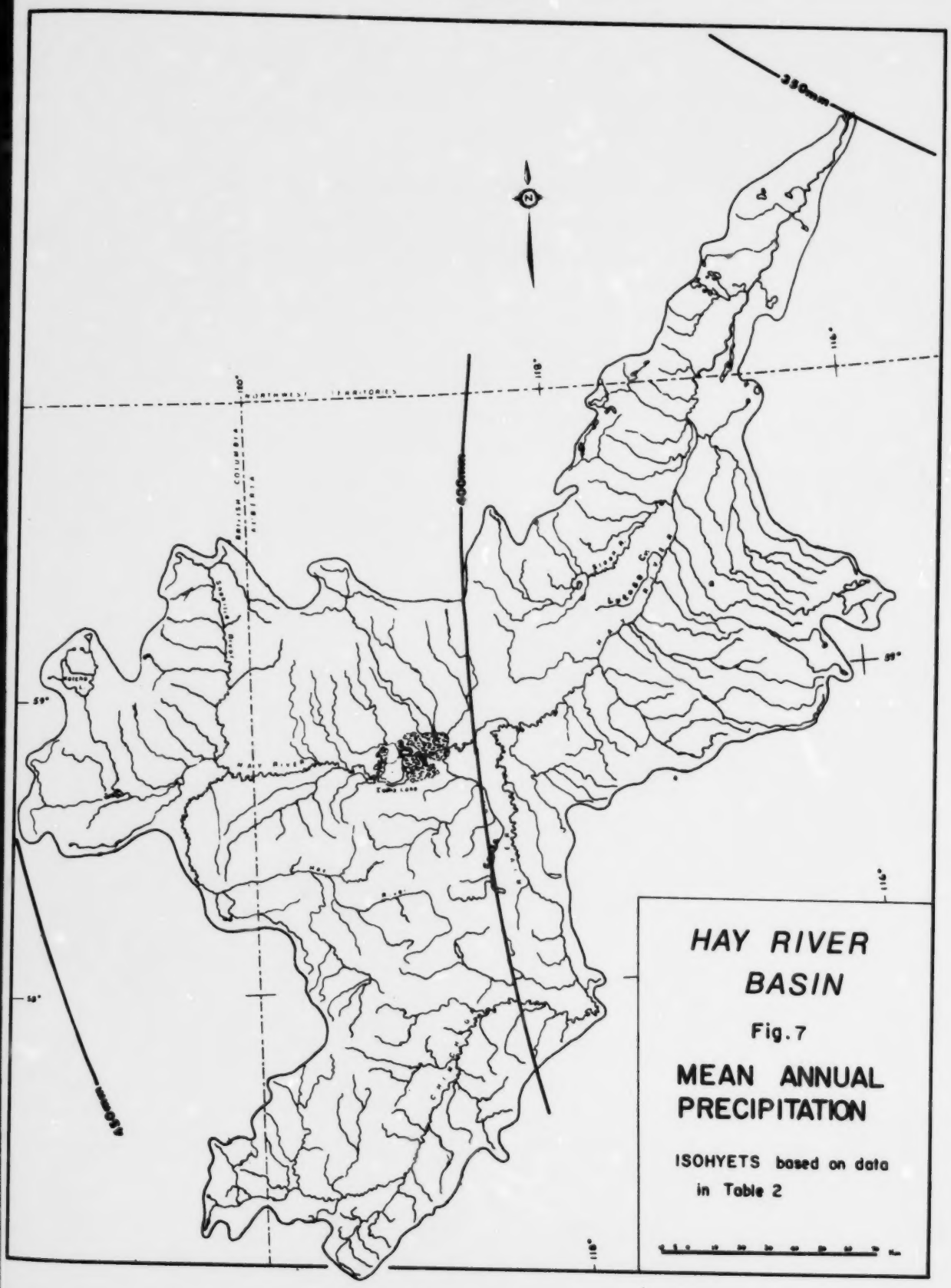
interest in climate for this overview is hydrometeorological. In this regard annual precipitation data from climatic stations nearest to the basin are of interest. Atmospheric Environment Services (personal comm., 1983) has provided the data shown in Table 2.

Table 2: Mean Annual Precipatation for 30-Year Period (1951-1980)

	To Zama L (km)	Total Precip (mm)	Snow (mm)
Fort Nelson, B.C.	230	451.8	186.5
Fort St. John, B.C.	310	492.6	221.9
High Level, Alta.	95	386.7	
Peace River, Alta.	295	375.1	
Hay River, NWT	260	339.9	

If Hay-Zama Lakes are taken as the approximate centroid of the basin, the relevance of the distance from weather stations to Hay-Zama Lakes becomes apparent. Based on these data, mean annual precipitation is estimated at 405 mm for the basin as a whole. It is quite evident however, that a precipitation gradient exists over the region with maxima to the west and minima to the east, as shown in the precipitation isohyets in Figure 7.

One of the characteristics of a continental climate equally applicable to the boreal environment is the occurrence of precipitation in each month of the year. Figure 8 illustrates monthly distribution of precipitation for the town of Hay River using mean data for the 1951-80 period referenced in Table 2. Clearly, there is a direct link between precipitation and temperature regimes; both attain maximum values in summer.


350mm
400mm
450mm
HAY RIVER
BASIN
Fig. 7
MEAN ANNUAL
PRECIPITATION
ISOHYETS based on data
in Table 2

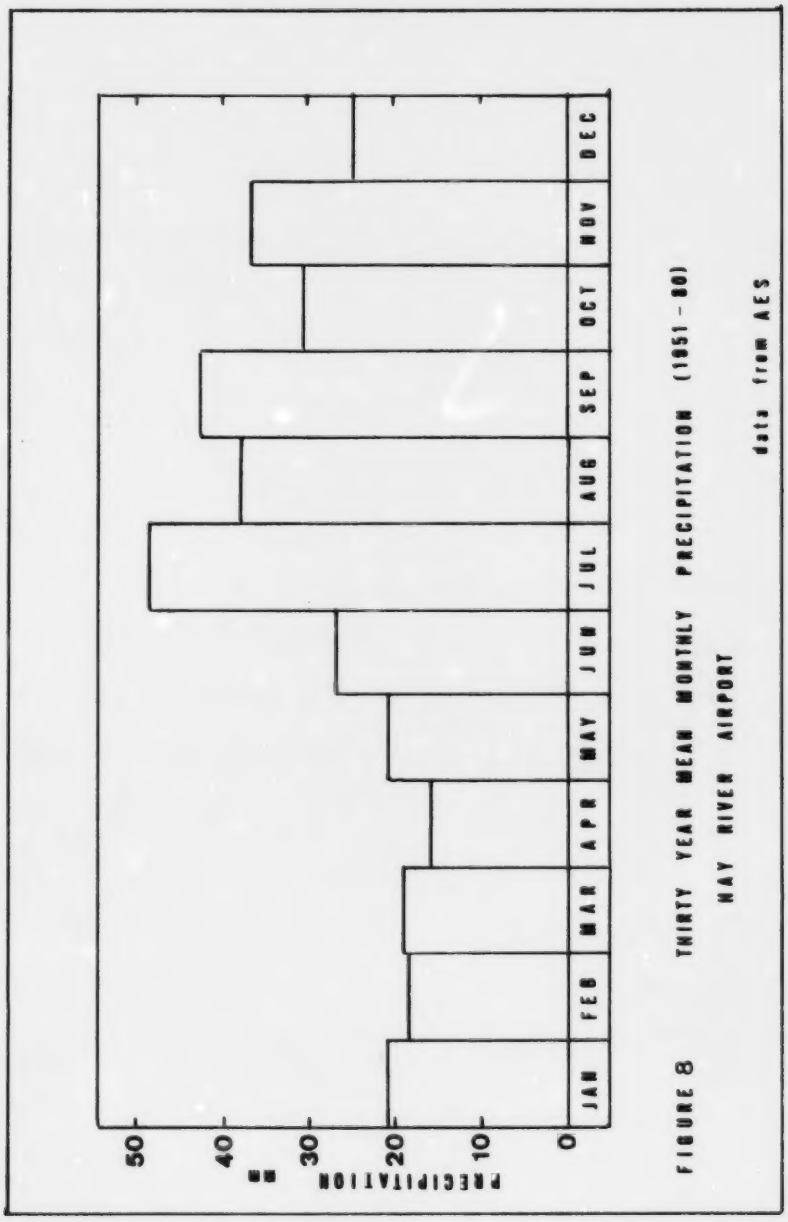


FIGURE 8 THIRTY YEAR MEAN MONTHLY PRECIPITATION (1951 - 80)
MAY RIVER AIRPORT
data from AES

2.6 Hay River Water Quality

Water quality data collected at the Hay River Community between 1960-1979 are reviewed below. Water quality data were also collected at Indian Cabins (June 1972-January 1974), Steen River (August 1969-January 1974), and near Meander River (August 1969-January 1974), Figure 9.

Water quality samples have been analyzed for water chemistry characteristics. No sediment analysis, invertebrate or algal community investigation have been carried out in the Hay River Basin.

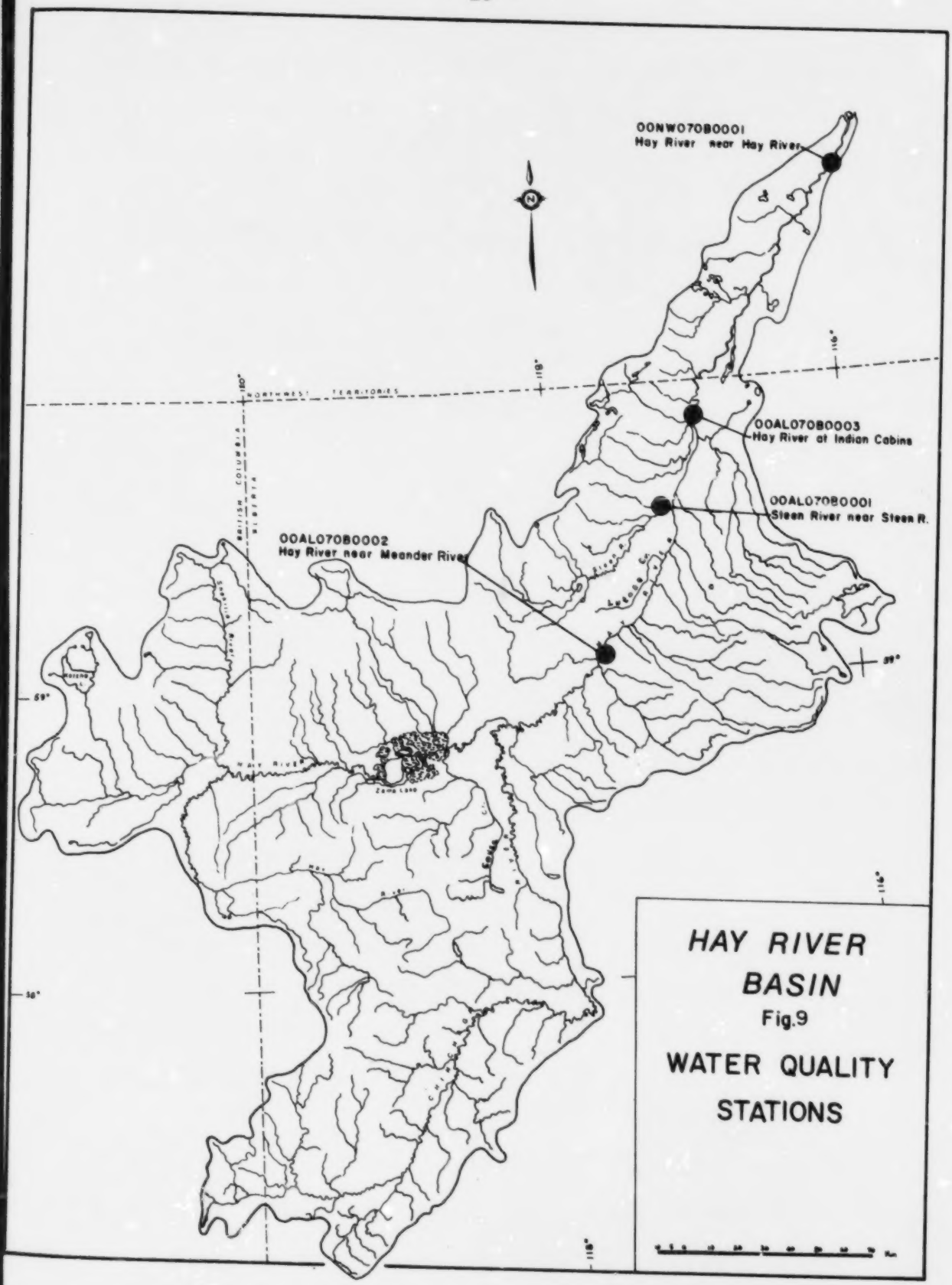
Data from the three sites upstream of the town of Hay River are sparse and have been excluded from analysis. All data presented below were collected by Inland Waters Directorate at ongoing sampling station OONW070B001. The data are subdivided into physical parameters, the major ions, nutrients, and metals. Key parameters are compared to surface water quality guidelines in the Conclusions (p. 26).

2.6.1 Water Chemistry - Physical Parameters

There is considerable variation over the period of record for physical parameters as shown in Table 3.

Table 3: Physical Parameters, 1960-1979 Water Quality Data
MacKenzie River Basin 1960-1979
Inland Waters Directorate, 1981

	Turbidity JTU	Colour Apparent Rel. Units	TDS mg/l	Spec. Cond. US/cm	pH	NFR mg/l
samples	37	35	30	25	8	22
low	2.1	30	78	217	7.6	2
high	225	600	527	821	8.4	1270
average	44.8	168	255	456		172
S.D.	63.4	132	142	214		340


00NW070B0001
Hay River near Hay River
00AL070B0003
Hay River at Indian Cabins
00AL070B0001
Steen River near Steen R.
00AL070B0002
Hay River near Meander River
NORTHWEST TERRITORIES
ALBERTA
Zama Lake
HAY RIVER
BASIN
Fig.9
WATER QUALITY
STATIONS

Turbidity is a measure of the suspended particles such as silt, clay and organic matter present in the water. The amount of solid material in suspension varies according to surface runoff, in-stream erosion, algal growth and land disturbances such as forestry, seismic activity and road construction. Turbidity in the Hay River Basin is closely related to discharge, rising sharply during spring freshet, then falling back during fall and winter low flows.

Apparent colour is a measure of the suspended particles and dissolved organic material in the water. Colour values are high in the Hay River basin, approximately six times higher than values from mountain streams. Leaching of the organic soils in the wetlands of the Fort Nelson Lowland area and probably throughout the basin, produces humic substances, tannins and lignins which likely account for the brown tinge associated with the Hay River. High values over the summer period reflect organic material from surface runoff, in-stream sources as well as from wetland drainage.

Total dissolved solids (TDS) and specific conductivity (Spec. Cond.) both measure dissolved substances in the water (e.g. sodium, chloride, magnesium, sulphate). Values for both groups of parameters are high in the Hay River Basin relative to mountain streams. They are highest during winter low flows when groundwater infiltration constitutes a higher proportion of flows.

The pH values are slightly basic, reflecting the carbonate (limestones and dolomites) geological features of the Hay River drainage. These

values remain relatively constant across the hydrograph and do not appear to be significantly affected by variation in discharge.

It should be noted that long term data have not been matched to the hydrograph. Average values do not reflect parameter values at a particular rate of discharge. The influence of discharge is therefore masked, and the degree of variability indicated by the data is exaggerated. NFR, for example, ranges from 2 mg/l to 1270 mg/l. A much lower range of variability will be observed if annual low flow NFR measurement and annual high flow NFR measurement are compared separately. For further analysis, the interested reader is referred to individual IWD NAQUADAT data.

2.6.2 Major Ions

The principal source of ions in natural waters is from mineralization. The concentrations and proportions of the ions will therefore vary according to bedrock geology. Data for major ions are presented in Table 4.

The major cations are potassium (K+), sodium (Na+), calcium (Ca2+) and magnesium (Mg2+), while the major anions are carbonate (CO3 2-), bicarbonate (HCO3-), chloride (Cl-), and sulphate (SO4 2-).

Table 4: Major ions, 1960 - 1979. Water Quality Data.
MacKenzie River Basin 1960-1979
Inland Waters Directorate, 1981

	Cations				Anions			
	K	Na	Ca	Mg	CO3	HCO3	Cl	SO4
samples	36	36	33	27	30	30	36	37
low	1.2	5.4	29.1	2.4	0	2	1.4	33
high	8.6	35.8	131	29.3	13	333	15.3	178
ave.	2.7	16.2	65.4	12.3	1	149	5.5	84.3
S.D.	1.2	9.4	31.7	7.4	3	90	4.1	42.9

The Hay River Basin has high values of bicarbonate, the principal buffer responsible for maintaining a stable pH. Calcium values are also high. Calcium together with magnesium constitutes the bulk of hardness in water. Calcium and bicarbonate originate from the limestone and dolomite bedrock in the basin. The water is therefore relatively hard and has good acid buffering capacity.

Sodium and sulphate values are also high relative to other basins in the NWT. The sodium could be mineralized from upper basin shale formations, or more likely from the Chinchaga halite formations, while high sulphate values generally indicate gypsum deposits.

An inverse relationship exists between ion concentration and discharge. Ion concentration is lowest during the high dilution period of freshet. Concentrations rise until they peak in winter when the groundwater, most likely the major source of ions to the system, constitutes the highest proportion of flows.

2.6.3 Nutrients

Nitrogen (N), phosphorous (P), and carbon (C) constitute essential ingredients required for the growth of plants. They may exist in a number of chemical forms as they are cycled through atmospheric, terrestrial and aquatic systems. Certain forms of nutrients at high levels may cause excessive nuisance aquatic plant growth, i.e. eutrophication, or may be toxic, both to aquatic life and to humans. Data for nutrient species are presented in Table 5.

Table 5: Nutrients, 1960-1979. Water Quality Data
Mackenzie River Basin, 1960-1979
Inland Waters Directorate, 1981

	Dissolved N NO3 and NO2	Dissolved P Ortho PO4	Total P	Total Organic Carbon
samples	33	29	10	25
low	<.005	<.002	.013	20
high	.588	.082	.13	39
ave.	.217	.016	.053	31.8
S.D.	.196	.017	.037	5.7

Nutrients may exist as organic or inorganic species, and may be present as dissolved or particulate constituents. The particular form will vary according to the exchange rate between dissolved and particulate species, biological growth cycles, the discharge regime and competition between biotic and abiotic factors. Lack of continuous data for each species over the period of record, as well as changes in analytical methods precludes detailed interpretation.

The Hay River Basin has high mean values of Total Organic Carbon, Dissolved Organic Carbon and Total Dissolved Phosphorous (MRB Water Quality Report Supplement 9: Section 5.3.2.1). The productive terrestrial systems of the Interior Plains, including shallow, organically rich wetlands, likely account for these values. The Total Dissolved Phosphorous levels reflect decaying vegetation and possibly regeneration from bottom sediments by wind induced circulation.

Further interpretation of the nutrient dynamics is hindered by:

> "...the quality of the data. Seasonal variations and relative species proportions are difficult to assess due to noncontinuous data for the individual species over

> each year. Evaluation of spatial variations are also limited by the inconsistency of species sampling at sites within each subbasin. All data comparisons, i.e. at each site, between sites and subbasins, and over time are impeded by the change in laboratories and analytical techniques over the period of record."
>
> MRBC Water Quality Report:
> Supplement 9, Section 5.3.2.1

2.6.4 Metals

Ambient waters are sampled for metal concentrations to determine whether they are above limits found to be toxic to aquatic organisms. Metals may also bioaccumulate in the food chain, leading to high levels in fish tissue and subsequently causing health concerns among humans consuming these fish. Background levels of metals occur naturally in freshwater, either in dissolved or particulate form. It is the dissolved form of the metal, particularly when present as a free ion, that is most readily available to aquatic biota.

Filtering of water samples while in the field is necessary to enable an analysis for dissolved metals but this is generally not practical in the north due to logistical constraints. The extractable analytical technique, used to produce the data for most of the metals presented in Table 6, results in metal concentrations combining the dissolved metal concentration and a variable amount of the metal found in particulate form. Medians, rather than average values, are used here due to the large number of "less than" values.

Table 6: Metals, 1960 - 1979. Water Quality Data
Mackenzie River Basin, 1960-1979.
Inland Waters Directorate, 1981

Metal	Samples	Low	High	Median	S.D.	*Analysis 1960-79	*Analysis 1980
Boron	22	.03	.23	.17	.04	D	D
Vanadium	18	<.05	<.05	<.05		E	T
Manganese	23	<.01	.37	.05	.09	E	E
Iron	22	.7	11.6	1.85	3.27	E	E
Cobalt	21	<.001	.008	.002	.002	E	T
Nickel	19	.004	.027	.009	.006	E	T
Copper	24	<.001	.023	.003	.006	E	T
Zinc	23	<.001	.05	.005	.014	E	T
Arsenic	16	<.0005	.013	<.005	.0037	D	D
Cadmium	22	<.001	.002	<.001	0	E	T
Barium	3	<.0	.1	<.0	0	E	T
Lead	8	<.00	<.05	<.001	.022	E	T

* Analysis: D - Dissolved
E - Extractable
T - Total

Manganese, iron, nickel, copper and zinc all have particularly elevated levels during freshet. This is due to particulates transported during spring runoff into the aquatic system as well as to increased erosion due to high energy spring discharge. Dissolved metals concentrate at their highest proportion during fall and winter low flows, although concentration levels in the Hay River are still low during these periods. Supportive data analysis is found in MRBC Water Quality Report Supplement 9: Section 5.4

It can be seen from Table 6 that 8 of the 10 metals formerly analyzed as "extractables" are now analyzed as "totals" - i.e. the sum of the concentrations in the dissolved and suspended fractions. Water quality data produced by this more precise technique continue to approximate earlier summarized data (See Detail Surface Water Quality Data - Northwest Territories, 1980-1981, Environment Canada).

2.6.5 Organics

Organic monitoring is generally subdivided into three groups, phenols/ oil and grease, PCB's and pesticides/herbicides. No organic monitoring has ever been carried out in the Hay River system. The phenols, oil and grease group is relevant to the oil and gas development in the Hay-Zama Lakes region. Significant contamination of downstream aquatic resources would initially show up as tainted flesh in the sports fishery and as taste and odour problems in drinking water supplies.

2.6.6 Conclusions

Physical parameters such as turbidity and colour are naturally high during freshet, while total dissolved solids and specific conductivity are at their highest concentrations during the winter low flows. Calcium and bicarbonate are high in the Hay River Basin, offering good buffering capacity to acid deposition, and reflect the carbonate surficial geology of the basin. Relatively high nutrient values originate from Interior Plains drainage and the shallow, productive Hay-Zama Lakes wetlands. Particulate nutrients are highest during freshet, whereas dissolved forms tend to peak in later summer at the conclusion of uptake by summer biota. Metals are typically found bound to clay or organic particulate material and are therefore at their highest level during peak discharge. No organic monitoring has been undertaken to date.

Key parameters are compared to drinking water and receiving water guidelines in Table 7. Total dissolved solids (TDS) are slightly over recommended limits, although it is most likely the case that the guideline is not applicable to Interior Plains rivers. TDS concentrations are at natural levels in the Hay River Basin and it is very probably that the aquatic biota are completely adapted to this level.

Copper levels are also above recommended limits although this too is likely a natural phenomena reflecting high sediment loads carrying bound copper which is unavailable to biota. Cadmium levels appear high but are of uncertain accuracy as the values are at the limits of possible detection.

Table 7: Comparison at 90th percentile values with surface water quality guidelines. Values in mg/l except pH. Guidelines from MRBC Water Quality Report Supplement 9: Appendix 6

	Aquatic Guidelines	Drinking Water Guidelines	90th Percentile	Mean - Median
TDS	400	500	508	225
pH	6.5-9.0	6.5-9.0	8.2	-
NO2-NO3	90	10	0.520	0.217
TP	0.05	-	0.114	0.053
Nickel	0.250	0.250	0.020	0.009
Copper	0.002	0.500	0.015	0.003
Zinc	0.200	5.0	0.039	0.005
Arsenic	0.050	0.050	0.009	<.005
Cadmium	0.0002	0.010	0.001	<.001
Lead	0.010	0.050	0.007	<.001

It should be emphasized that 90th percentile comparison with the guidelines represents the worst case scenario. Also, guidelines have not been developed specifically for northern NWT surface waters. The Hay River Basin data generally represent water quality at background natural levels.

The one major data gap which does exist is for organic (petroleum hydrocarbons) parameters. An organic monitoring program based on the identification of source loadings with the basin, should be designed to ascertain potential downstream impacts from upstream oil and gas activity.

2.7 Hay River Hydrology

2.7.1 River Pattern

Examination of Figure 3 illustrates that on the macro-scale at least, the drainage system within the Hay River Basin is typically dendritic as would be expected on low relief terrain. Even at this scale, however, there are a few elements of river pattern which imply underlying structural control. It can be seen, for example, that the Chinchaga River main stem in the vicinity of 58° north latitude hugs the eastern drainage divide, well away from mid-drainage as in an ideal dendritic system. Structural control is also evident in the upper Hay River drainage above Hay-Zama Lakes; here the headwaters of the Hay River flow first to the west, then north in B.C. and finally

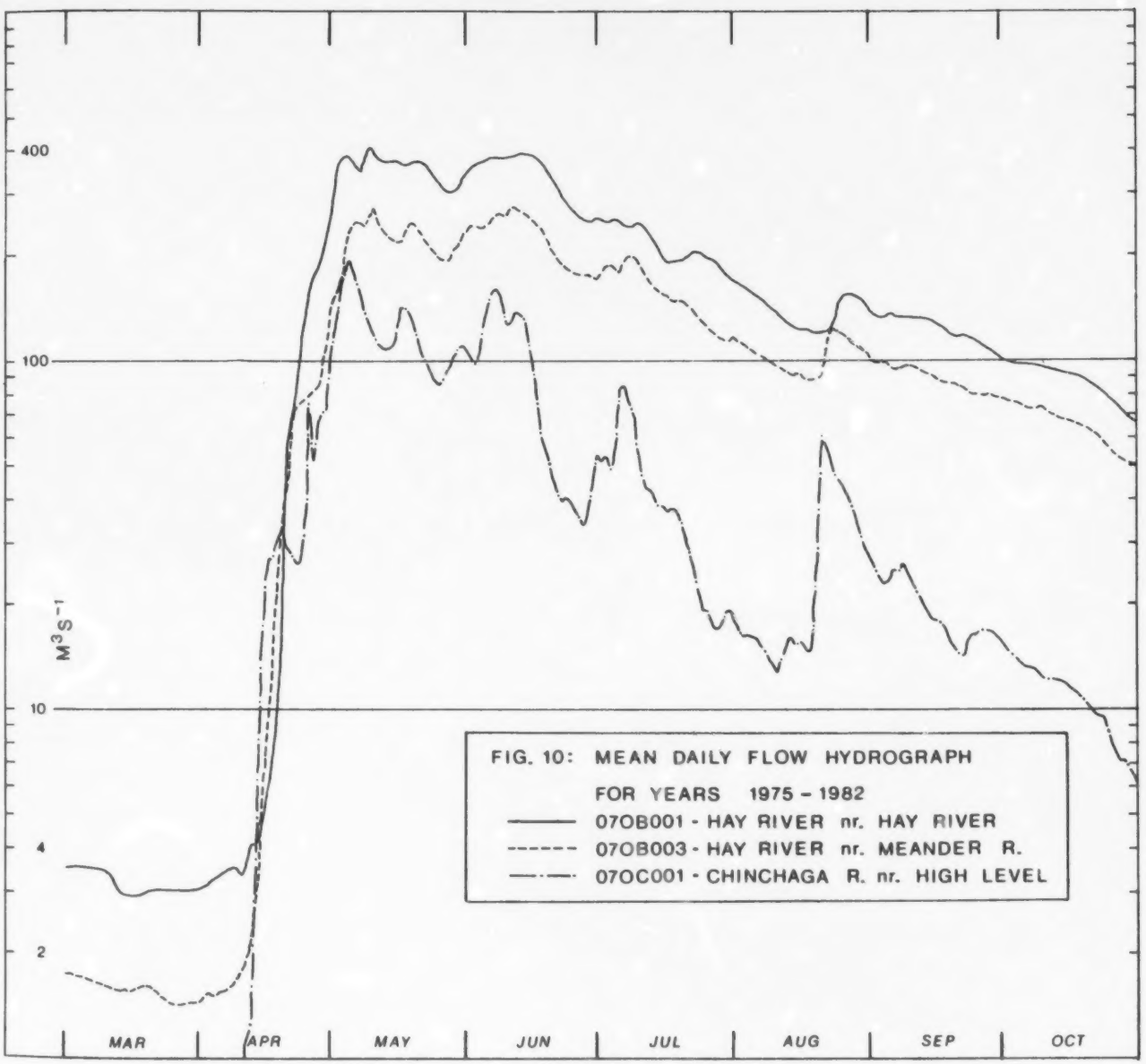
back to the east in order to circumvent a high-elevation moraine lying between it and the lake. The morainal ridge shows up clearly in basin profile B-B1 in Figure 5. Although the drainage network appears to be well-developed at the gross regional scale, there are indications that this is not the case when examined at the basin or tributary scale, thus giving rise to extensive wetland tracts in the Fort Nelson Lowlands, especially in the region around Hay-Zama Lakes (MRBC, 1982). Wetlands have a profound effect on surface runoff for several reasons. First, they retard water flow because they behave as storage reservoirs for inputs from rainstorms or snowmelt. Second, such stored runoff has good opportunity to infiltrate the underlying soils because the excess water is in shallow reservoirs and thus covers greater land areas than would deeper lakes with similar water volumes. Third, the shallow waters and associated extensive tracts of aquatic vegetation contribute to substantial water loss through evapotranspiration. We would therefore expect responses to water inputs in the Hay River basin to be somewhat attenuated by virtue of the extensive wetlands.

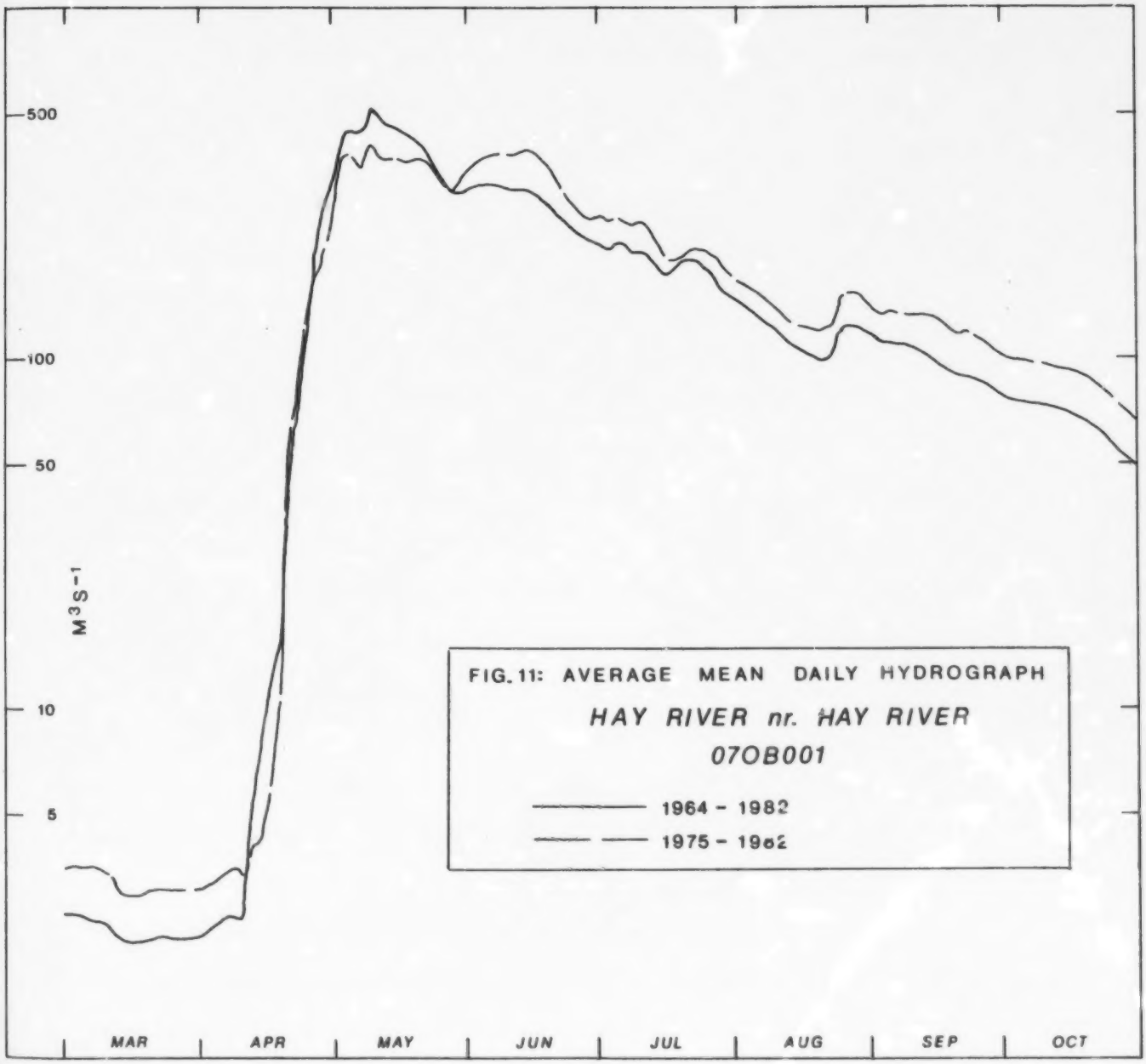
On the other hand, the absence of lakes minimizes the effects of storage in the Hay River catchment. The National Atlas of Canada (1970) suggests that lake area is only one to three percent of land area of the Hay River Basin, which proportion would be negligible in terms of runoff regulation of the basin. In the Hay-Zama Lakes area, two small dams were constructed to conserve wetland habitat in dry years. Despite these dams, the streamflow regime for the basin is considered as natural.

2.7.2 The Annual Runoff Cycle

As is common in sub-arctic and arctic drainages with little or no natural storage, the Hay River exhibits great seasonal variation in its runoff. Runoff from snowmelt is the dominant event and attains flood proportions when heavy rains coincide with the snowmelt. Occasional high periods of mid-summer flow result from major rainstorms; in the years with low snowfall, the summer rains can sometimes produce the annual flood. Average annual flow hydrographs, Figure 10, for Hay River near Hay River, Hay River near Meander River and Chinchaga River near High Level are derived from day-by-day averages for the common period of record, 1975 to 1982. The figure illustrates the characteristic rainfall peaks in June, July and August. When a longer period of record, Figure 11, is considered, the dominance of the spring flood becomes apparent, although the rainfall peaks in July and August are still distinguishable.

When the long-term daily average flows for the Chinchaga River, 070C001, and for the Hay River near Meander River, 070B003, are compared, the analysis clearly shows the effect of Hay-Zama Lakes storage complex. For Hay River, less than one-half the total annual runoff occurs in May and June while the same months at the Chinchaga River station include nearly two-thirds of the year's total flow.


400
100
10
4
2
M³S⁻¹
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
FIG. 10: MEAN DAILY FLOW HYDROGRAPH
FOR YEARS 1975 - 1982
07OB001 - HAY RIVER nr. HAY RIVER
07OB003 - HAY RIVER nr. MEANDER R.
07OC001 - CHINCHAGA R. nr. HIGH LEVEL


500
100
50
10
5
M3S-1
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
FIG. 11: AVERAGE MEAN DAILY HYDROGRAPH
HAY RIVER nr. HAY RIVER
07OB001
1964 - 1982
1975 - 1982

Base flow is important in winter periods because the effects of snowmelt or rainfall events are largely removed. Base flows result from groundwater discharges and in the case of Hay River, from the draining of wetlands. Even in the exceptionally low flow year, 1980, wintertime base flows did not drop below 2 cubic meters per second (m^3/s). There remains, however, a large difference annually between late winter base flows and the yearly flood; differences in the range of two orders of magnitude, i.e. from 2 m^3/s to 200 m^3/s in 1980, or from 8 m^3/s to 1080 m^3/s in 1977.

The lack of basin storage is emphasized by the very sharp rise in the discharge hydrograph at the commencement of spring freshet (Figure 11) which fact gives rise to an annual flooding problem in Hay River settlement. At Hay River the spring rise of water is associated with the annual ice run on the river and this happens before Great Slave Lake ice breakup. Resulting ice jams in the Hay River estuary create high water levels far in excess of those caused by high river flows without any ice present, such as can occur in summer from rainstorms within the catchment.

In Figure 11, the sharp rise in early April is taken to indicate the beginning of breakup. Application of this criterion to each annual record from 1969 to 1982 therefore allows us to assess the variability of spring breakup. The analysis shows that the average date of breakup is April 16; the earliest is April 03; the latest is April 30. The standard deviation of the breakup date is ±8 days, which means that 68 percent of the time, the breakup will fall within 16 days centred about April 16.

2.7.3 Extreme Flow Events

From the previous section it is clear that both floods and low-flows exhibit great variability from year to year. It becomes necessary therefore to collect such data for many years in order to derive a good estimate of the size of an average flood or of an average minimum flow. In the case of Hay River near Hay River, the station with the longest period of record, 18 years, the average flood was determined to be 743 m^3/s - this average derived from the years 1964 to 1981 inclusive.

Statistical calculations indicate that a 20-year flood, that is, a flood which has a five percent chance of happening in any year, is 1440 m^3/s when calculated by the Gumbel I method, and 1180 m^3/s when calculated from a normal distribution. The normal distribution was considered to be most reliable.

For low-flow analysis, seven-day minimum flows from each of the 18 years were extracted from the flow record and subjected to similar analysis. The average seven-day low flow, for 1964-1981, was 1.8 m^3/s at the Hay River station near Hay River, NWT with a five percent chance that the low flow in any given year will be greater than 6.8 m^3/s and less than 0.25 m^3/s. Caution is advised in the use of these data because the error magnitude of this estimate is fairly large.

2.7.4 Data Extension

2.7.4.1 Monthly Means

Of the two main stem stations, near Hay River and near Meander River, the period of record at Hay River is longer by eleven years and is

continuous, in contrast to the seasonal, open water record near Meander River. It was considered feasible to extend the data for the station near Meander River by mathmetical fitting using least squares. The best-fit equation of relation between Meander River and Hay River monthly mean flows was Equation 1. Its use permits the extension of monthly mean flow record for Hay River near Meander River, number 070B003, back to 1964, and to expand the annual record from eight to twelve months.

Equation 1: $Y=0.716X - 1.12241$

where Y=monthly mean flow (m^3/s) at Hay River near Meander River
and X=monthly mean flow (m^3/s) at Hay River near Hay River

The synthetic record should be viewed with some caution, however, since the standard error is 21 percent.

2.7.4.2 Annual Floods

Generally, the results from mathematical correlation between the two stations on the Hay River were sufficiently poor to preclude any good definition of the relationship. Comparison of Hay River near Hay River floods with those from the Chinchaga River produced better results but two years of poor agreement, 1975 and 1979, prevented a definitive statement. Perhaps a review of the data base might improve the results for flood flow correlation.

2.7.4.3 Annual Yield

It was not possible to compare annual total flows of the two main-stream stations directly since only seasonal records exist on the up-stream station in Alberta. For purposes of mathematical comparison

and extension of short-term records, March to October totals were calculated for Hay River near Hay River to make those data comparable to the upstream data. The analysis suggests the equation:

$$Y=0.71244X - 0.650626$$

where Y=Annual Mean Flow at Hay River near Meander River
and X=Annual Mean Flow at Hay River near Hay River

Data derived from this equation can in turn be converted to extended records of annual yield and annual unit runoff.

2.8 Calculation of Flow at Jurisdictional Boundaries

In its most elementary form, the calculation of water flow at jurisdictional boundaries is an apportionment of discharge on area criteria alone which assumes basin-wide homogeneity of hydrologic factors.

Technical arguments can be presented which suggest that the assumption of homogeneity is not strictly true in the comparison of the data from the two main stem Hay River stations; the analysis suggests a five percent adjustment to the upstream station.

Rather than use daily flow data from a specific year for calculation of flow apportionment at the NWT border, it was decided to use the average daily flow record described in an earlier section which was derived by averaging flows day by individual day for the period of record. Daily means were adjusted by area decrease; the flow at the NWT border was taken to be 45 000/47 900 (90 percent) of the flow at Hay River with no lag.

There were insufficient data to produce daily estimates of discharge at the two border crossings on the B.C./Alberta border; the storage effects of the Hay-Zama Lakes region are unknown and they are situated between Sites 1 and 2, at the B.C. border and the nearest stream-flow stations, as shown in Figure 12. The catchments upstream of sites 1 and 2 were thought to be sufficiently similar, physiographically, to those of the Chinchaga River and of Sousa Creek to permit estimates to be made at the monthly mean flow level. The data used were mean monthly flows for the period of record. Estimates of Site 1 and 2 discharges were based on catchment area ratios. For Site 1 the data were produced independently from both Sousa Creek information and from Chinchaga River data. The simple mean of these was taken to be the best estimate since it accounts for hydrologic variability related to area differences. For Site 2, the estimated data were based on Chinchaga River only since the two catchments are similar in size. The results are shown here in Table 8.

Table 8: Monthly Mean Flows at B.C./Alta. border on Hay River Main Stem

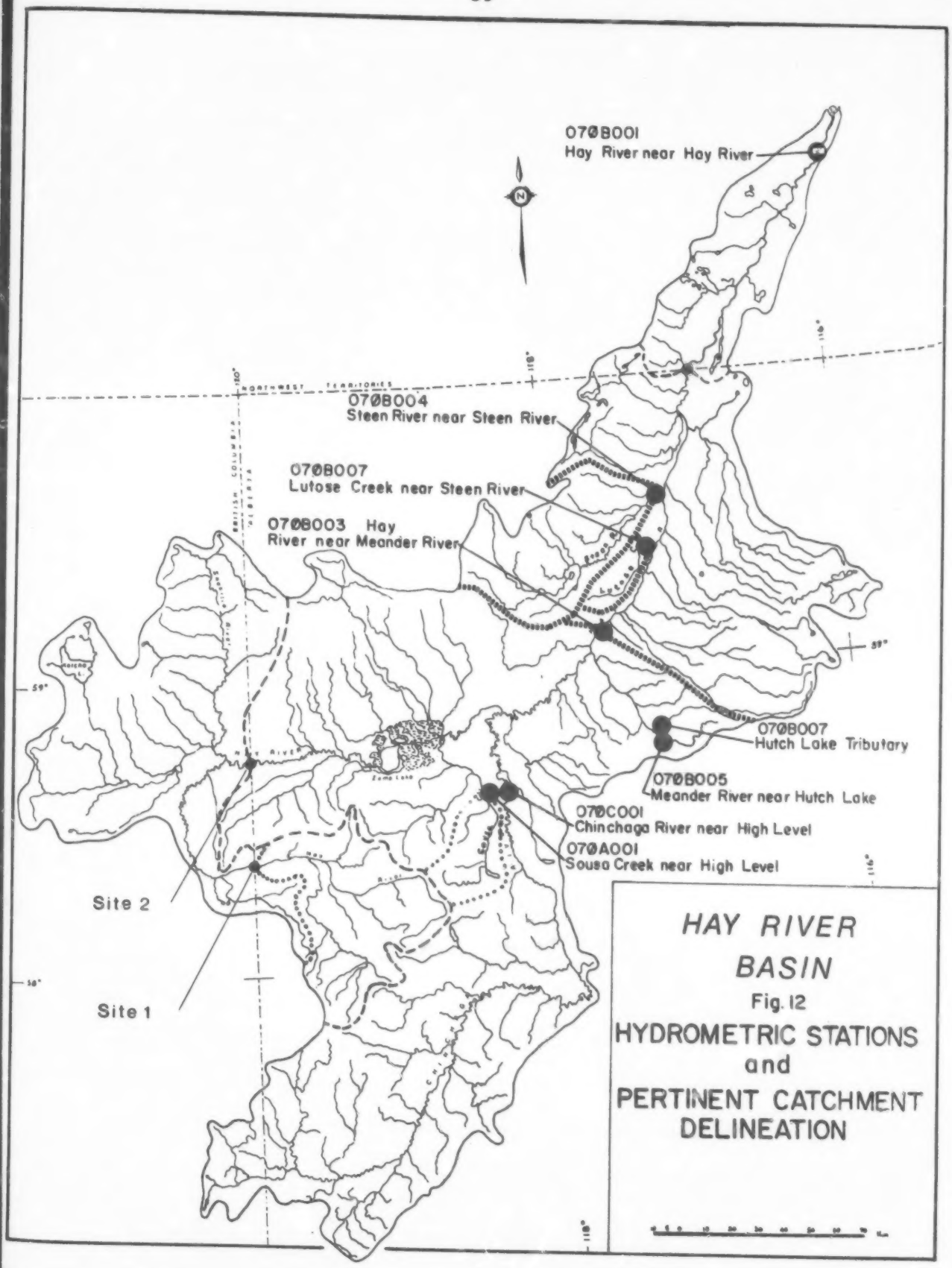
	Site 1 Monthly Means From Chinchaga River	Site 1 - From Sousa Creek	Average	Site 2 Means From Chinchaga River
JAN	0.192	-	0.192*	0.735
FEB	0.038	-	0.038*	0.528
MAR	0.113	0.007	0.060	0.433
APR	11.6	6.55	9.08	44.6
MAY	43.3	26.2	34.8	165.0
JUN	21.7	22.3	22.0	82.8
JUL	12.5	6.84	9.67	47.9
AUG	7.21	6.55	6.88	27.5
SEP	4.93	3.87	4.40	18.8
OCT	2.96	2.21	2.59	11.3
NOV	0.880	-	0.880*	3.36
DEC	0.359	-	0.359*	1.37

* Chinchaga River Data only

Conversion Factors:

Site 1 Monthly Means from Chinchaga River:	0.274
Site 1 From Sousa Creek:	3.619
Site 2 Means from Chinchaga River:	1.046

Site 1 Drainage area:	2 960 km²
Site 2 Drainage area:	11 300 km²
Chinchaga River Drainage area:	10 800 km²
Sousa Creek Drainage area:	818 km²


07ØB001
Hay River near Hay River
07ØB004
Steen River near Steen River
07ØB007
Lutose Creek near Steen River
07ØB003 Hay
River near Meander River
07ØB007
Hutch Lake Tributary
07ØB005
Meander River near Hutch Lake
07ØC001
Chinchaga River near High Level
07ØA001
Sousa Creek near High Level
Site 2
Site 1
HAY RIVER
BASIN
Fig. 12
HYDROMETRIC STATIONS
and
PERTINENT CATCHMENT
DELINEATION

3.0 HAY RIVER BASIN RESOURCE USE

3.1 Special Areas

For this report, "Special Areas" will be defined as:

a) Ecological:

Areas which 1) are unique sites or are of particular importance because of their biological productivity or cultural and social value; and 2) can be expected to suffer serious loss in value it changes are imposed on their hydrology (MacKenzie River Basin Study Report Supplement 1, 1981); or

Areas identified by other sources (e.g. IBP Sites, Territorial or Federal Reserves, etc.)

b) Tourism/Recreation:

Are either campground, picnic areas, scenic areas, Territorial or Federal parks.

Figure 13 indicates the Ecological and Tourism/Recreation sites located within the Hay River Basin.

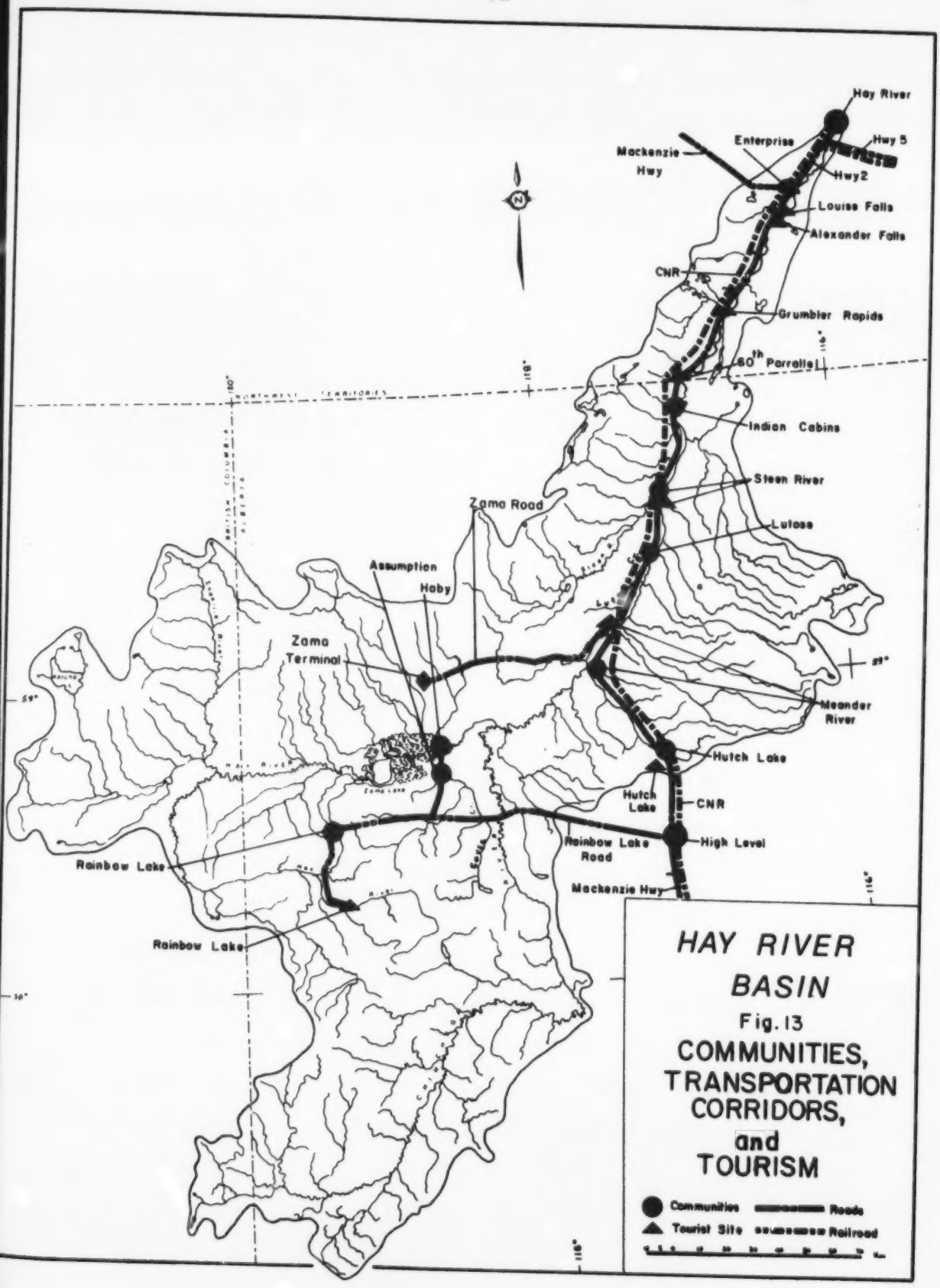
3.1.1 Within the Northwest Territories

Ecological:

There are no known significant ecologically unique areas in the NWT portion of the Hay River Basin.

Tourism/Recreation:

There are three campgrounds (60th Parallel, Hay River and Louise Falls), two day-use areas (Alexander Falls and Escarpment Creek) and one "view-point" (Grumbler Rapids) in the NWT section of the Hay River


Hay River
Enterprise
Hwy 5
Mackenzie Hwy
Hwy2
Louise Falls
Alexander Falls
CNR
Grumbler Rapids
60th Parrallel
Indian Cabins
Steen River
Zama Road
Lutose
Assumption
Haby
Zama Terminal
Meander River
Hutch Lake
Hutch Lake
CNR
Rainbow Lake Road
High Level
Rainbow Lake
Mackenzie Hwy
Rainbow Lake
HAY RIVER BASIN
Fig. 13
COMMUNITIES, TRANSPORTATION CORRIDORS, and TOURISM
Communities
Roads
Tourist Site
Railroad

Basin (Figure 13). All of these sites, except the 60th Parallel, use some aesthetic aspect of the Hay River for their tourist attraction. A golf course is located just outside the town boundary at Hay River.

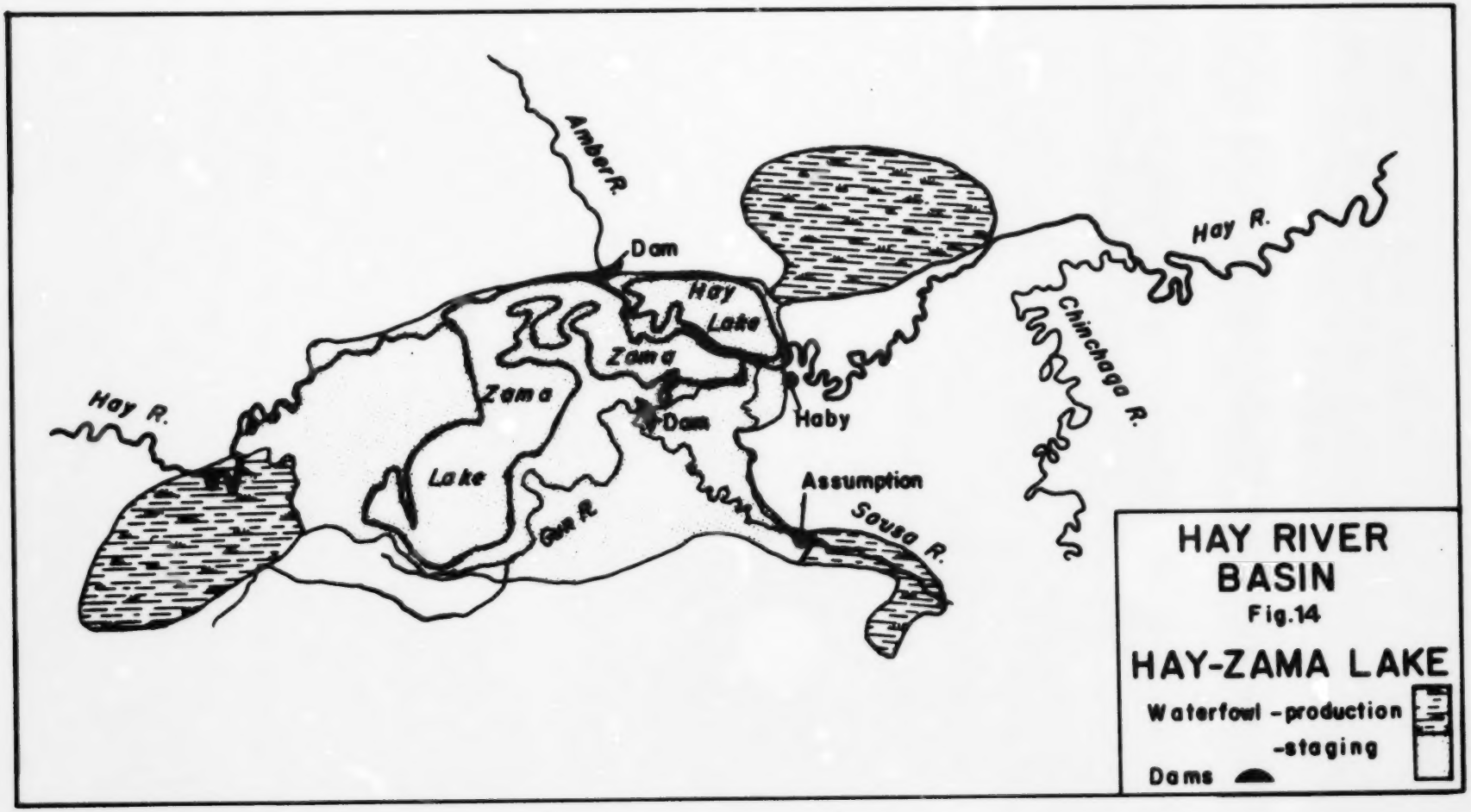
3.1.2 Outside the Northwest Territories

Ecological:

The Hay-Zama Lakes wetland complex, in Alberta, is the only significant ecological area identified in the Hay River Basin (Figure 14). This area is listed by the Mackenzie Basin Committee as a "Sensitive Area" (Mackenzie River Basin, Study Report Supplement 1, 1982). The complex of lakes, ponds and marshes has high duck production capability (Canadian Wildlife Service, 1979). The area is also extensively utilized by ducks, geese and swans for feeding and staging during spring and fall migrations. The Canadian Wildlife Service considers the area one of prime importance for waterfowl habitat in Alberta.

Tourism/Recreation:

There are four developed campgrounds in the Alberta region of the Hay River Basin (Rainbow Lake, Hutch Lake, Meander River and Steen River, Figure 13). The Rainbow Lake campground is the only one utilizing the Hay River itself, located near its headwaters on Rainbow Lake. Hutch Lake is a well-developed facility on a small lake, with day-use and overnight areas. The Meander and Steen River facilities are small roadside campgrounds with very limited recreational potential.


Amber R.
Dam
Hay
Lake
Zama
Zama
Lake
Dam
Hay R.
Haby
Assumption
Sousa R.
Gar R.
Hay R.
Chinchaga R.
HAY RIVER
BASIN
Fig.14
HAY-ZAMA LAKE
Waterfowl - production
-staging
Dams

3.2 Resource Use Within the Northwest Territories

3.2.1 Forestry

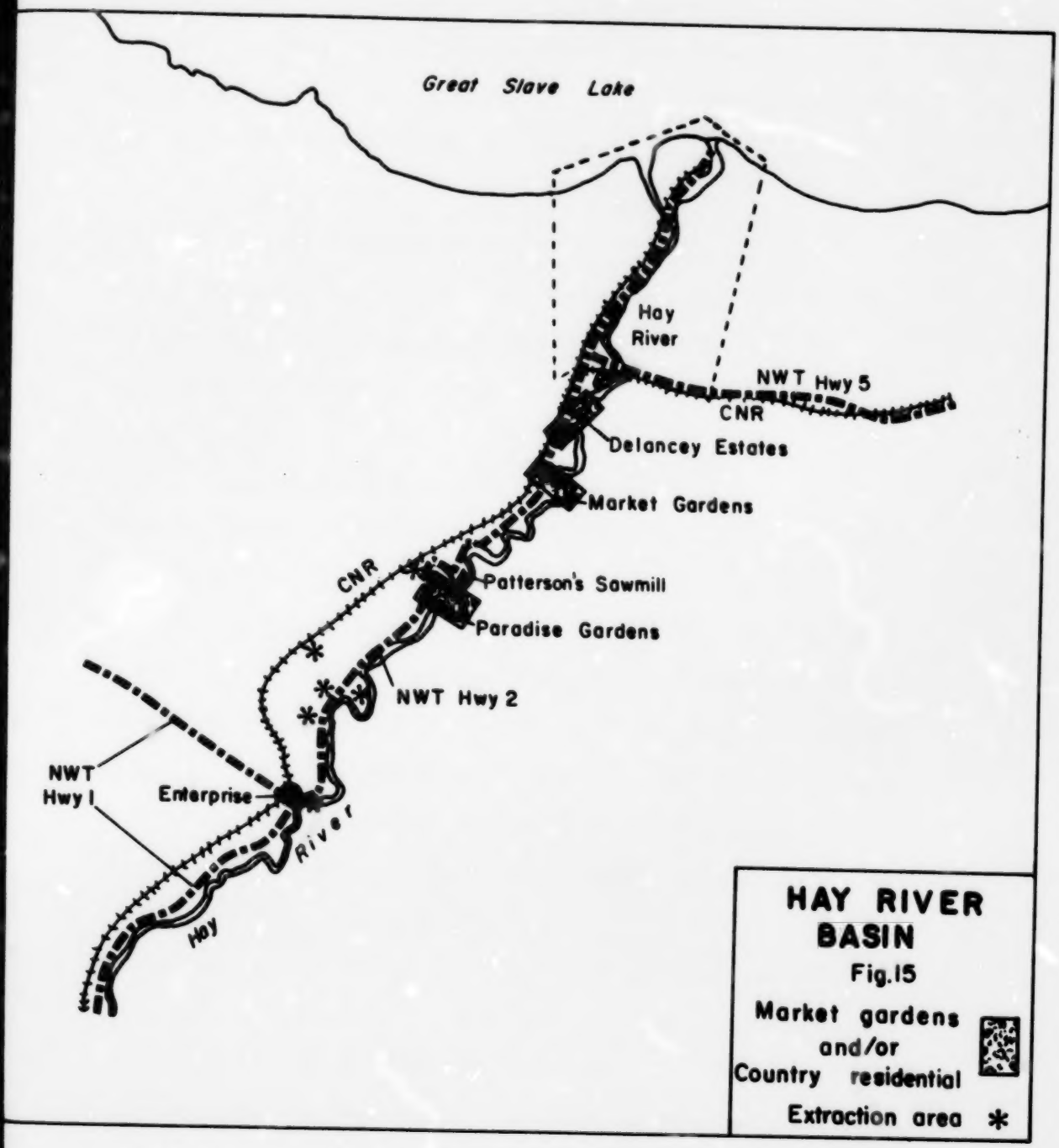
Patterson's Sawmill is located within the basin, on the banks of the Hay River between the towns of Hay River and Enterprise. The harvest timber area is located in the Cameron Hills just west of the basin's border. The basin was previously logged out, but still maintains a high capability for forestry in the future.

3.2.2 Agriculture

There are four areas of developed "market gardens" in the NWT portion of the Hay River Basin: Enterprise, Paradise Gardens, Market Gardens and Delancey Estates (Figure 15). These gardens are limited to vegetable crops and are generally sold within the immediate vicinity. Ben Greenfield, the largest producer in the area, produced $ 7 000 of goods in 1983 (B. Greenfield, pers. comm., 1983).

A 395 ha area of grain production is located just north of the Alberta/NWT border. The crop is primarily rape seed which is trucked to High Level and marketed by the Alberta Wheat Pool.

There are approximately 2 000 ha of Class 3 soils suitable for market gardens within the Hay River Corridor. Presently 47 ha are being utilized and 16 ha are identified for expansion (B. Larson, pers. comm., 1984). This area is identified as having the greatest potential for agricultural expansion (B. Larson, pers. comm., 1984). These areas are shown in Figure 15.


Great Slave Lake
Hay River
NWT Hwy 5
CNR
Delancey Estates
Market Gardens
CNR
Patterson's Sawmill
Paradise Gardens
NWT Hwy 2
NWT Hwy 1
Enterprise
Hay River
HAY RIVER BASIN
Fig.15
Market gardens and/or Country residential
Extraction area

3.2.3 Mining

There is no active mining in the basin. The only extractions are from sand and gravel borrow pits, however, there have been some explorations for lead/zinc deposits in the valley (DIAND - land use permits, 1983-1984). No commercial mining has yet been proposed.

3.2.4 Dams and Impoundments

There is potential for hydroelectric development at Alexandra and Louise Falls (Ferguson, Simek, Clark Ltd., 1983). However, there are no plans to develop either of these sites.

3.2.5 Transportation Corridors

Transportation corridors in the NWT are illustrated in Figure 13. The Mackenzie Highway, NWT Highway No. 1, parallels the west side of the Hay River from the Alberta/NWT border to Enterprise. At this point, the Mackenzie Highway proceeds northwesterly and NWT Highway No. 2 proceeds north, parallel to the Hay River, to the town of Hay River. NWT Highway No. 5 branches east and crosses the Hay River approximately 14 km south of the town of Hay River. Approximately 45 000 vehicles crossed the border and travelled north in 1982.

The Canadian National Railway also parallels the west side of the Hay River immediately south of the Highway No. 5 river crossing, the eastern branch of the railway crosses the Hay River and proceeds 87 km to the settlement of Pine Point. This line was previously called the "Great Slave Lake Railway". However, it is now known as the Meander River sub-division and extends 607 km from the Roma Junction near Peace River to the town of Hay River (M. Devine, 1982). The line is

an important link to the Mackenzie River barge system, which loads at Hay River. . In 1981, a total of 3 963 carloads of goods were transported to Hay River and 505 carloads to Pine Point. The major commodities transported were fuels, chemicals, building supplies, steel and pipe. Each car is capable of gross weights exceeding 100 tonnes. In 1982, 869 037 tonnes of lead concentrate and 8 981 tonnes of zinc concentrate were produced in Pine Point and shipped out. There is little potential for new corridors to be developed, but upgrading of existing ones can be expected.

3.2.6 Communities

There are three communities, Enterprise, Hay River and the Hay River Reserve in the NWT portion of the Hay River Basin (Figure 13). The town of Hay River is located at the mouth of the Hay River, on the shores of Great Slave Lake and on Vale Island. The 1980 population was 3 322 (Devine, 1982), and its economy is mostly dependent upon private enterprise. The major work revolves around the Mackenzie River barge traffic and loading from the CNR. The other major industry is commercial fishing. However, due to a declining market and increased marketing costs, this has been reduced from previous years.

In both 1951 and 1963 there was extensive flooding on Vale Island (Devine, 1982). This has resulted in most of the recent land development occurring on the adjacent mainland.

Linked to the town of Hay River is the Hay River Reserve. Located on the east bank of the east channel of the Hay River and the south shore

of Great Slave Lake, and encompassing 1 818 hectares, it is one of two reserves in the NWT. The main employment of the 298 residents is trapping.

Enterprise, located at the junction of the Mackenzie and Hay River Highways, had a 1980 population of 40 (Devine, 1982). The main income is from highway service activities.

No appreciable expansion is expected for any of these communities due to the limited development potential of the area.

3.2.7 Hunting and Trapping

Practically all of the NWT section of the Hay River Basin is utilized for hunting and trapping (Land Use Information Series, DIAND, 1975). In 1982, a total of 73 trappers from Hay River and Hay River Reserve took in a total of $ 107 958.05 in furs. (Devine, 1982).

The area can be arbitrarily divided into two sections. The northern section is primarily used by the older trappers from the town of Hay River area. The southern section is utilized by trappers from both Alberta and the Northwest Territories. Lynx, mink, and marten form the main harvest in winter, while beaver and muskrat are taken in spring. Moose and woodland caribou are also hunted in this area.

All of the available areas for hunting and trapping are zoned and all are presently utilized.

3.2.8 Other

3.2.8.1 Fishing

The lower section of the Hay River from Great Slave Lake to Louise Falls is utilized by domestic fishermen. Pike, walleye and suckers are taken in the spring, and whitefish and inconnu are caught in the fall. The open water season is also used by sports fishermen for pike and walleye.

3.2.9 Excluded Uses

The following resource uses have been excluded primarily as they are not present in the NWT portion of the basin:

oil and gas production - petrochemical - industrial

3.3 Resource Use Outside the Northwest Territories

3.3.1 Forestry

The Hay River Basin is in the Boreal Forest Region. The main tree species are white spruce, black spruce, lodgepole pine, balsam fir, tamarack, trembling aspen, black poplar and white birch.

The present commercial forestry is limited to small sawmill operations, with some cutting and transportation to the large mill at High Level. The areas of lumbering are small and generally located along the Rainbow Lake Road, with some along the Mackenzie Highway (Alberta Forest Service, Timber Management Branch, July, 1979).

Most of the area has a rating of Class 4 (Canada Land Inventory, Land Capability for Forestry, 1970) for commercial forestry. This class is defined as "lands having moderately severe limitations to the

growth of commercial forests". There are patches of high grade lumber along the lower Hay River and Chinchaga Rivers. The forestry potential of these patches, however, is limited by the long rotation time required to generate more than one crop.

Also, the limited availability of pulp materials and water have prevented a pulpmill facility from being located in the Hay River Basin (Alberta Forest Service, Timber Management Branch, July, 1979). Therefore, small-scale types of forestry operations have no detrimental effects on the existing downstream water users nor is it expected to hinder any future resource developments.

3.3.2 Agriculture

There is no commercial agriculture in the Hay River Basin outside the NWT due to soil and climatic limitations. Most of the soils are classified as "Class 4" or higher (Canada Land Inventory, Land Capability for Agriculture, 1972) and are defined as soils having sufficiently severe limitations for agriculture to restrict the range of crops and often require specialized treatment to allow their use at all.

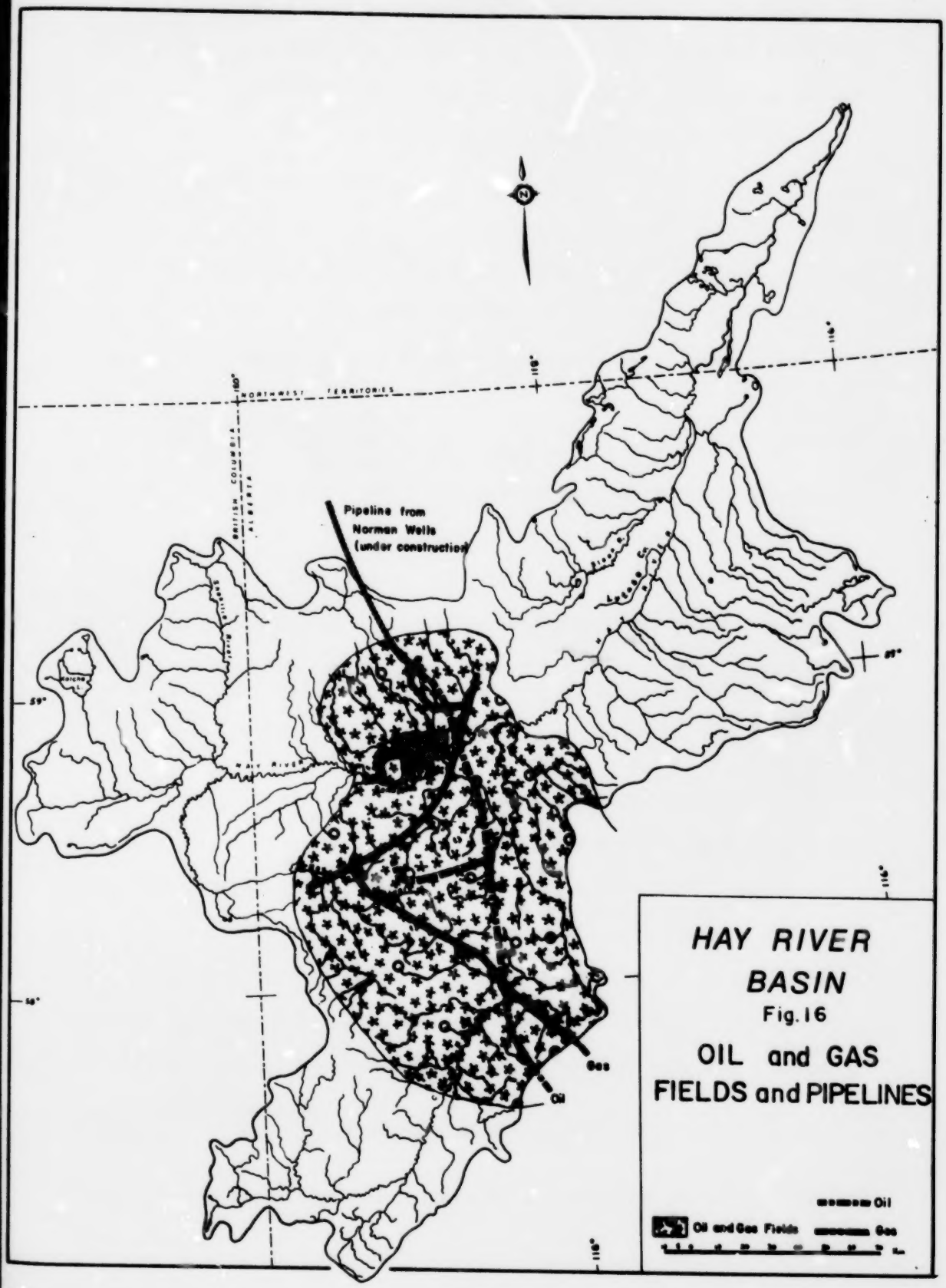
3.3.3 Mining

There are, at present, no known, commercially feasible ore bodies in the Hay River Basin. There are some coal deposits, but they are not of a commercial grade or quantity (Alberta Energy and Natural Resources, Mineral Support Branch, pers. comm., 1983).

3.3.4 Oil and Gas Production

There are three major oil and gas fields in the Alberta portion of the Hay River Basin. (Energy Resources Conservation Board, 1983). The Rainbow Field is one of Canada's largest producing oil and gas fields. These fields are congregated around the Hay-Zama Lakes complex and continue south-easterly out of the Hay River Basin (Figure 16).

Also related to this development are the collecting and main transportation pipelines. The main oil and gas pipelines cross the Hay River just to the east of Hay Lake, by the settlement of Haby (Figure 16). The oil pipeline, owned by Rainbow Pipeline Company, is a 50.8 cm (20 inch) pipe, and carries approximately 2 000 m^3/day from the Zama fields (A. Peterson, pers. comm., 1983). Farther south, this line combines with an oil pipeline from the Rainbow field. The 50.8 cm pipeline, which crosses the Chinchaga River, has a daily volume of 12 000 m^3 (A. Peterson, pers. comm., 1983). The gas pipeline, owned by NOVA, is a 50.8 cm pipe, carrying approximately 25 500 m^3 day (N. Karren, pers. comm., 1983).


Pipeline from
Norman Wells
(under construction)
HAY RIVER
BASIN
Fig. 16
OIL and GAS
FIELDS and PIPELINES
Oil
Oil and Gas Fields
Gas

The Hay-Zama pipeline is proposed to be connected to the Norman Wells pipeline in 1985. This will increase the volume of oil flowing across the Hay River from 12 000 m^3/day to approximately 16 000 m^3/day (A. Peterson, pers. comm., 1983).

Strand Oil's field, within the Hay-Zama area, is due to come online into the Norman Wells-Hay/Zama pipeline in later summer (1984), and input 3 000-4 000 barrels per day (P. Airhart, pers. comm., 1984).

During the 82/83 year, 179 new well sites, 126 roads and 50 pipelines were built; and in the 83/84 year, 160 well sites, 98 roads and 66 pipelines were built (Alberta Forest Service, Geophysical Survey, Rainbow Lake District, 1984). With this amount of activity in the area, the potential for a transportation or transfer spill of resupply fuels is high. The actual effect upon the Hay River will depend upon the proximity of a spill to the river.

The release of hydrocarbons from the present wells, producing or exploration, is thought to pose little if any environmental threat to the Hay River from occurrences such as spills into the river system. However, the salt water injection wells or disposal wells could pose potential environmental problems from contamination of ground-water aquifers. There is little information available at this time to enable analysis of the potential for environmental concerns related to salt water injections.

The existing air strips have little to no effect on the actual Hay River Basin.

The greatest environmental hazard from oil and gas development is posed by a spill from a failure in a pipeline. To date the record for the Hay-Zama pipelines has been excellent with only minor seepages reported.

Oil lines accounted for 15 percent of all pipeline failures in Alberta for 1975 to 1982 with gas accounting for the other 85 percent (Cameron, 1983). Crude oil lines were the most susceptible with approximately 90 percent of all oil line failures and the majority of these were caused by corrosion. Failures occur at an average rate of 3 per 10 000 operating km of pipe per year. The possibility exists then, that the additional pipeline in the area may result in additional failure.

3.3.5 Petrochemical - Industrial

There are no refineries or petrochemical plants within the Hay River Basin and it is not expected that any will be built within the near future. Gas processing plants are present but are not considered to pose any environmental problems. This is due to the nature of the operation and also their distances from the Hay River or its tributaries.

3.3.6 Dams and Impoundments

There are two small dams located in the Hay-Zama Lakes complex (Figure 14). One is on the Gun River and the other on the Amber River. The dams are used to retain spring flood water over the summer period, and have virtually no effect on the downstream natural flow regime of the Hay River.

3.3.7 Transportation Corridors

The Mackenzie Highway (Alberta Highway No. 35) and the Canadian National Railways both parallel the Hay River from the settlement of Meander River to the Alberta/NWT border (Figure 13). They both cross the Hay River approximately 32 km north of Meander River.

The two other developed roads in this area of the basin are the Rainbow Lake and Zama roads. The Rainbow Lake Road branches west off the Mackenzie Highway approximately two km south of the town of High Level and extends west through the settlement of Rainbow Lake and then south to Rainbow Lake. A secondary road branches north to the settlements of Assumption (Chateh) and Haby. The Zama Road branches west off the Mackenzie Highway approximately seven km north of the settlement of Meander River and continues to the main Zama pumping and collecting station, north of the Hay-Zama Lakes area.

The majority of the Hay River Basin in the area of the oil fields (Figure 15) is criss-crossed by cutlines and truck trails.

Direct environmental impact of the transportation corridors is minor once they are built. The main concern derives from corridor usage and subsequent spills from accidents. The major cause of spills in Alberta for 1980 and 1981 was truck overturns, comprising 31.1 percent of all spills reported (Krechtel, 1982). In the Northwest Territories, transportation accounts for 34.6 percent of the petroleum spills (Renewable Resources, 1983).

Potential development in the NWT will bring about increased transportation of goods along the northern routes such as the Mackenzie Highway and the Canadian National Railway to Hay River and Pine Point.

Increased transportation of petroleum products or hazardous chemicals along the corridors will raise the probability of accidents and spills. A spill at any of the river crossings could adversely affect the downstream water quality.

3.3.8 Communities

There are nine settlements in the Alberta area of the Hay River Basin. Two, Haby and Assumption (Chateh), are located by the Hay-Zama Lakes complex (Figures 13 & 14). The settlement of Rainbow Lake is approximately 40 km to the southeast of Hay-Zama Lakes. The six remaining settlements (Hutch Lake, Meander River, Slavey Creek, Lutose, Steen River and Indian Cabins) are all situated along the Mackenzie Highway (Figure 13). As well, a permanent camp, at the Zama Lake pumping and collection terminal, is located approximately 18 km north of Hay/Zama Lakes.

Due to limited industrial and recreational potential in the Hay River Basin, it is unlikely that any new communities and/or large expansion of present communities will develop.

The existing communities are of such a small size and have such a low level of industrial development that they pose no serious threat to the Hay River aquatic environment.

3.4 Summary

To date, the ongoing activities in the upper section of the Hay River Basin have had no effect on the Northwest Territories portion of the Basin. However, two areas of concern may arise in the near future:

1) Oil pipeline crossings on the Hay and Chinchaga rivers; and
2) Salt water spills or oil seepage.

The completion of the Norman Wells-Zama pipeline will result in an increased volume of crude oil crossing the rivers. The effects of a major spill at either crossing could probably extend over the downstream length of the Hay River and adversely affect all downstream residents.

Insufficient data exists to determine the potential effects of seepage, and/or groundwater dispersal of salt water associated with oil and gas production in the Hay River Basin. However, most fresh water organisms have an extremely low tolerance to changes in salinity. With the extensive oil and gas fields located in the upstream areas of the Hay River Basin, salt water pollution could become evident in the downstream areas of the basin. The probability of this occurring would depend on groundwater discharge of salt water to the Hay River, expecially when river flows are low due to natural stream flow fluctuations. This combination would increase the salt concentration in the river so that it may have deleterious effects on the downstream aquatic environment.

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APPENDIX "A"

LETTER OF UNDERSTANDING
BETWEEN
INLAND WATERS DIRECTORATE, ENVIRONMENT CANADA
AND
RENEWABLE RESOURCES, GOVERNMENT OF THE NORTHWEST TERRITORIES

Purpose

Since transboundary waters are the concern of both the federal government and the involved provinces and territories, the ultimate management of these waters was the topic of Recommendation 1 in the MacKenzie River Basin Study report. Recommendation 1 states that:

> "It is recommended that the jurisdictions at an early date conclude an agreement through which trans-boundary water management issued such as minimum flows, flow regulation, and water quality can be addressed at jurisdictional boundary crossing points in the MacKenzie River Basin, and which establishes a permanent board to implement the provisions of the agreement."

For the MacKenzie River and its tributaries, the Government of the Northwest Territories is understandably concerned about the impact of upstream water-related developments, diversions or regulation of the MacKenzie watershed. The Government of the Northwest Territories, along with Environment Canada, will also be participants in the negotiation process to work toward an agreement for water courses crossing the Northwest Territories boundary. The Department of Environment, and Inland Waters specifically, has interjurisdictional responsibilities under the Canada Water Act related to such a transboundary agreement and a responsibility to develop programs to collect data for both water quality and quantity in proximity to interprovincial boundaries.

In anticipation of formal agreements being struck between provinces and territories, the Government of the Northwest Territories, represented by the Department of Renewable Resources, and the Government of Canada, represented by the Inland Waters Directorate, DOE, hereby agree to undertake a joint study of those interjurisdictional river basins which are sub-components of the MacKenzie River Basin and which lie partly within the Northwest Territories.

Scope of Study

There are eight identified transboundary rivers within the MacKenzie River Basin for which basin overviews will be prepared. Phase I, in fiscal year 1983-84, will see the preparation of overviews for the Hay, Peel, Big Fish, Buffalo, Little Buffalo and Talston Rivers. Phase II in the following year will undertake overview preparation for the Slave and Liard Basins. It is proposed to develop the Hay River Basin as a prototype overview in order to eestablish format and content for the remainder of the study.

Specific Undertakings

Initially IWD, Yellowknife, with some assistance by Renewable Resources, will assemble physical data for the basins in question except for water quality descriptors which will be incorporated after the release of MRBC report, Volume 9. Specifically these will include information on location, gross and relative size, geographic aspects

such as geology, physiography, relief, basin shape, aspect, climate, flood and low-flow runoff regimes and dependable flows. Hydrologic parameters will be derived from published hydrometric data or from the application of Acre's (1982) regional equations.

Renewable Resources, GNWT will provide information for biological and socio-economic aspects which will include information on a basin's biophysical aspects, renewable and non-renewable resource base, the past, present, and future resource utilization within a basin, settlements, roads, pipelines and other human interactions which contribute to environmental change. Much of the biological and socio-economic information will be dependent on data supplied by the province or territory sharing the inter-jurisdictional basin.

Report production and distribution will be a joint IWD-Renewable Resources effort.

Timing

IWD and Renewable Resources agree to prepare six basin overviews by March 31, 1984 in the following sequence:

1. Hay River
2. Peel River
3. Big Fish River
4. Buffalo River
5. Little Buffalo River
6. Taltson River

Changes to the order or timing will be by mutual, written consent.

Costs

Exclusive to salary, costs for this joint study are not expected to exceed $ 3,000.00 per year for items such as computer time, maps and report printing. IWD and Renewable Resources agree to share these costs on a 50-50 basis as documented by IWD.

"H.A. Monaghan"
ADM, Renewable Resources

"D.A. Davis"
Regional Director, IWD